THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

THE INSTITUTION OF

PRODUCTION ENGINEERS JOURNAL

10 CHESTERFIELD STREET . LONDON . W1 Telephone: GROsvenor 5254/9

Vol. 36, No. 9 *Price 10/-* *September 1957*

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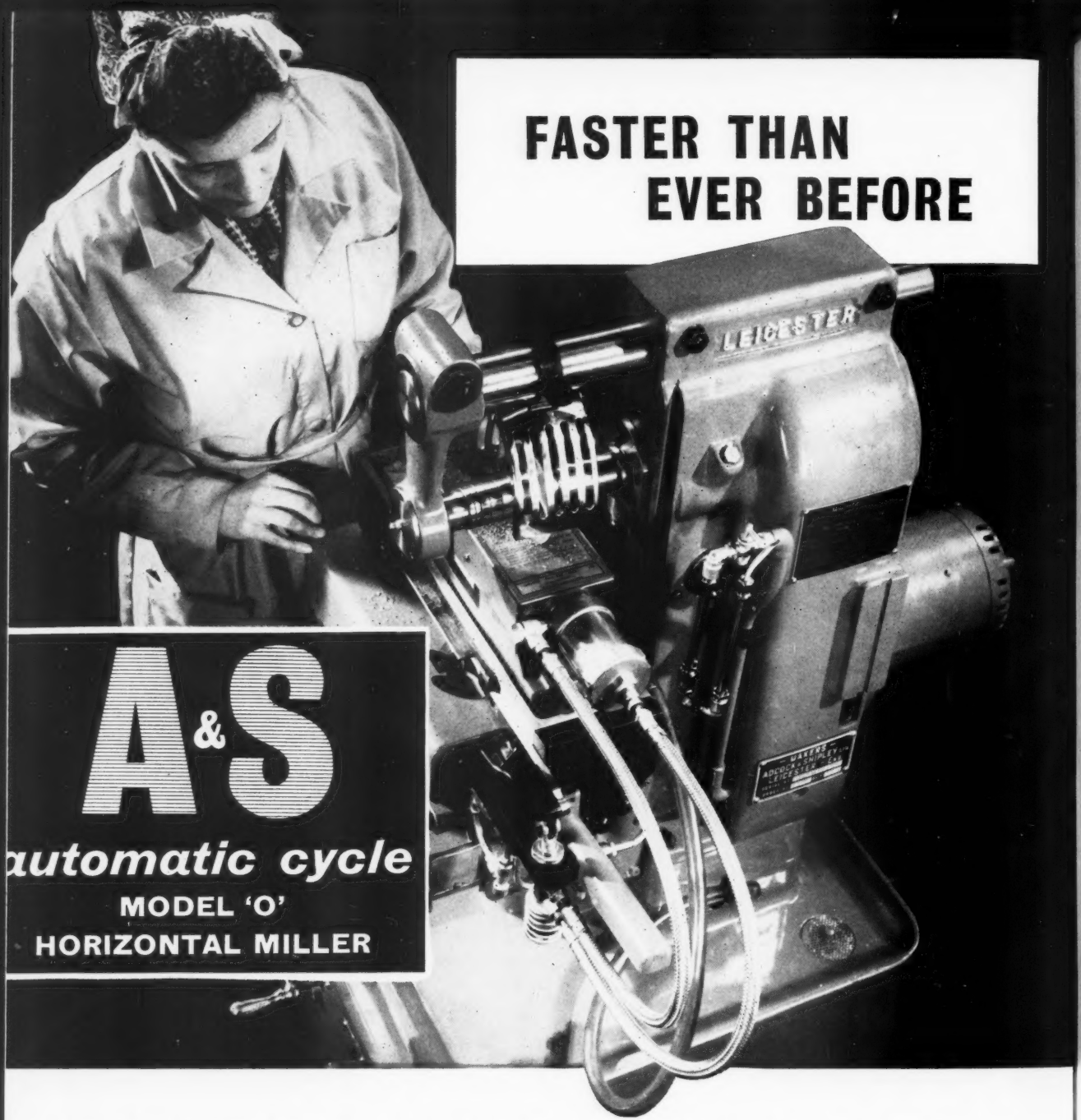

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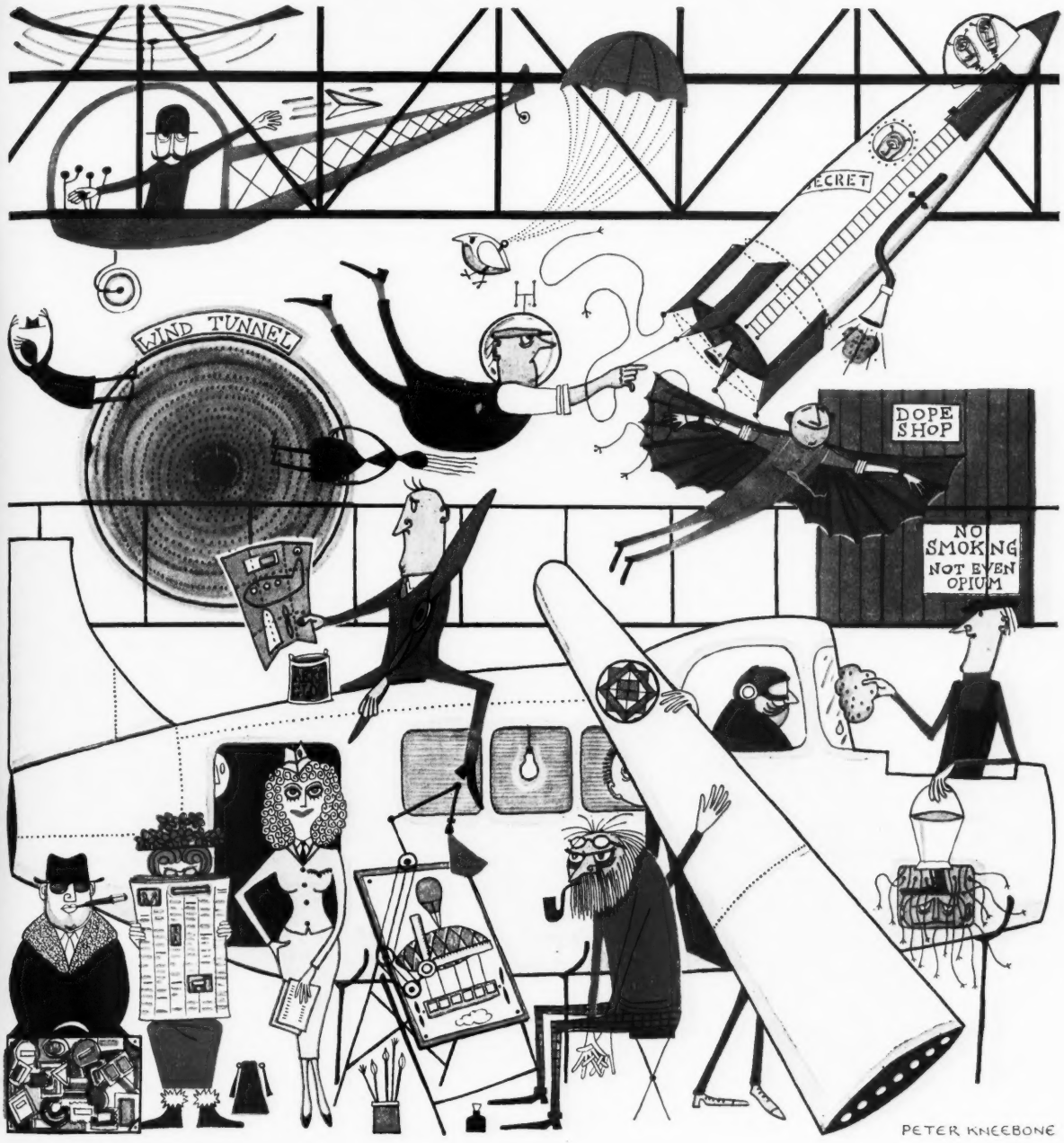

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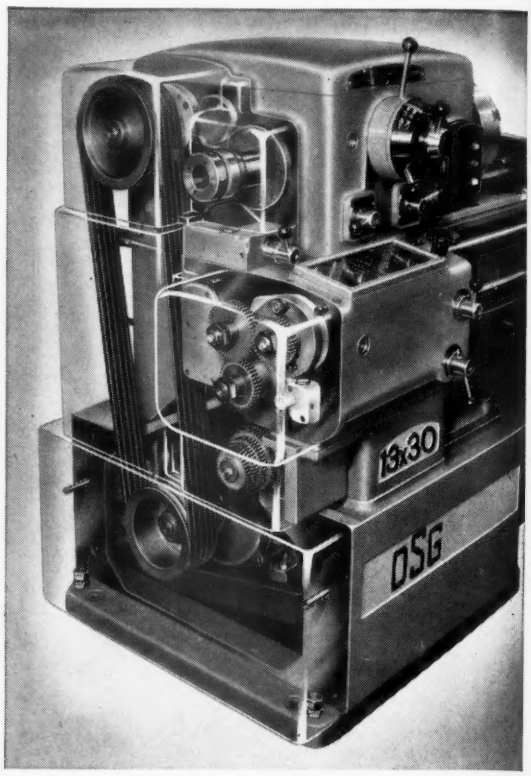

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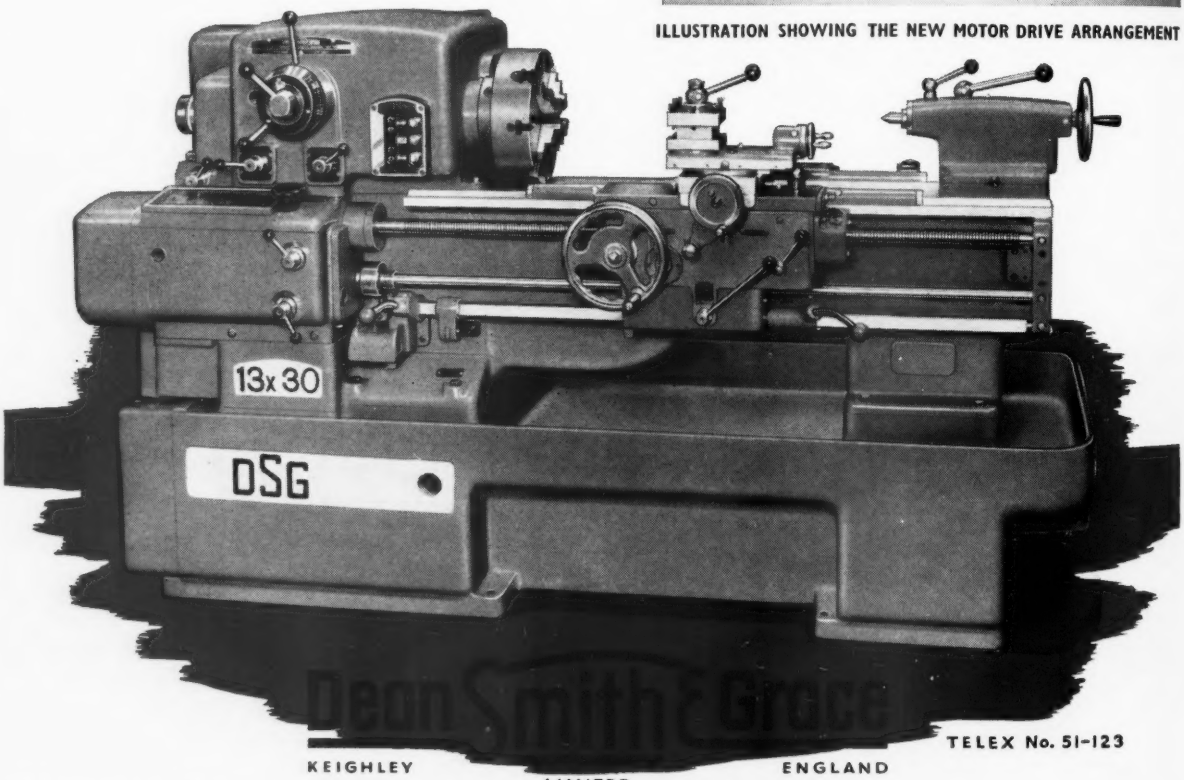

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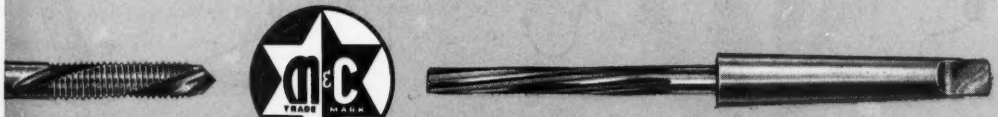

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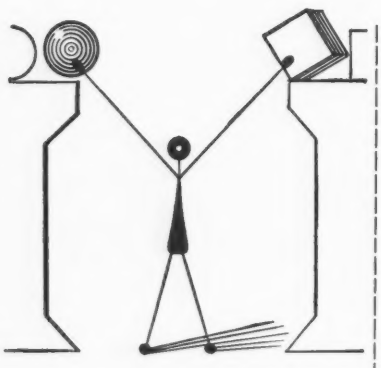
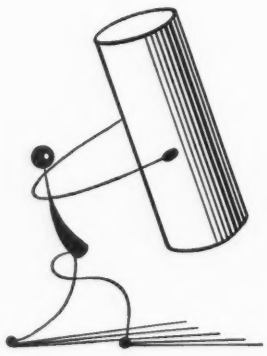
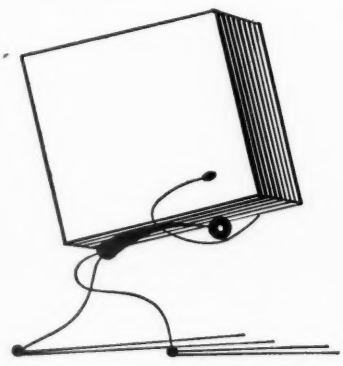


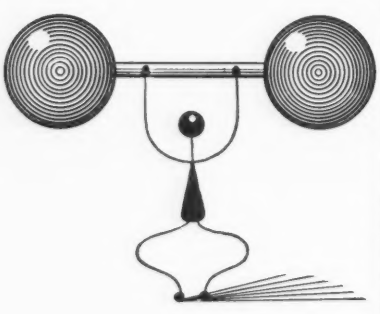
...reach...



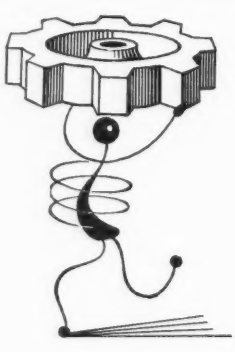
...grasp...



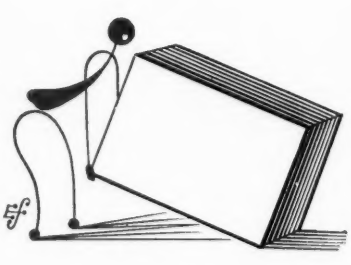
...carry...



...lift...



...turn...



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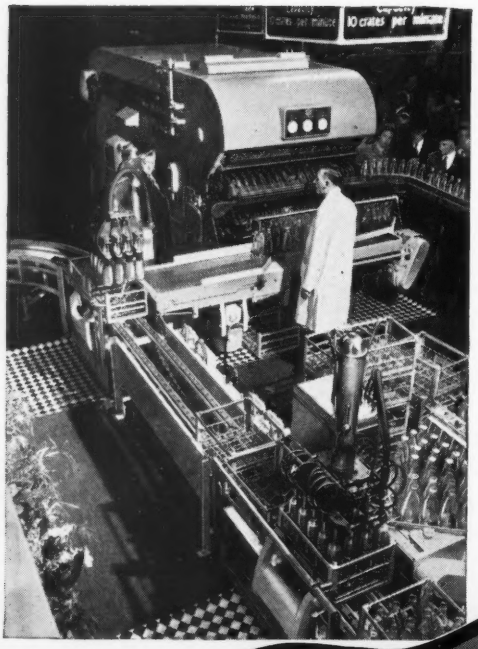

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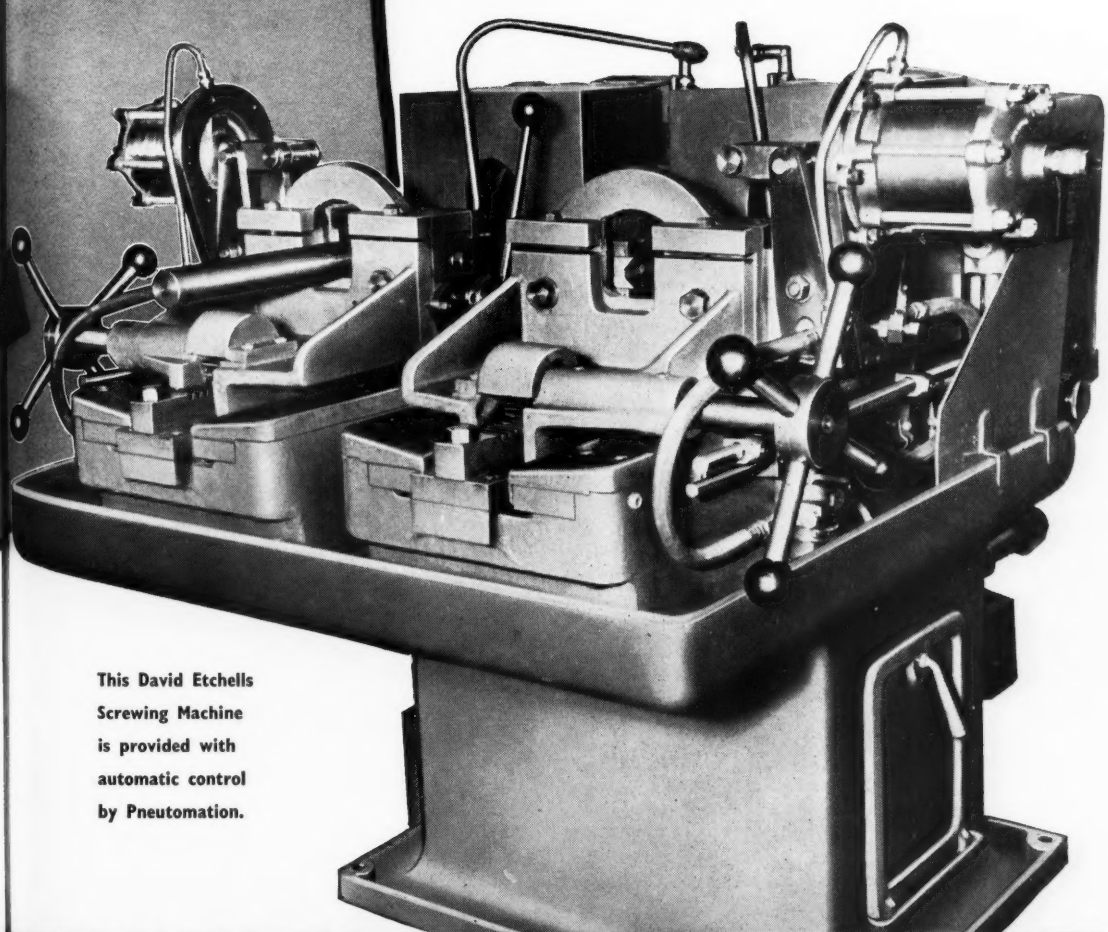

This David Etchells Screwing Machine is provided with automatic control by Pneutomation.

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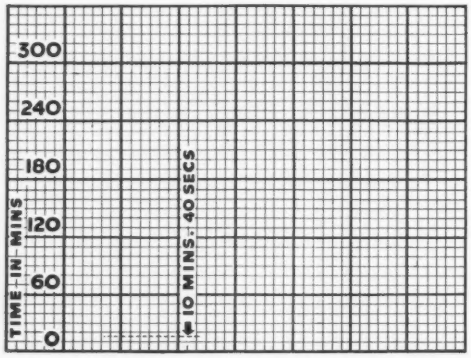
P.152

Vibration test of self-locking set screw

The divisions between the horizontal lines on the graph represent intervals of 60 minutes. Each vertical band represents a screw tested when subjected to vibrations at the rate of 1,750 cycles per minute. It can be seen that the Plain Cup Point screws most favourable duration test was 10 minutes 40 seconds, before shaking loose. The Knurled Cup Point screws remained tight after 300 minutes — representing 525,000 cycles of vibration — after which tests were discontinued.



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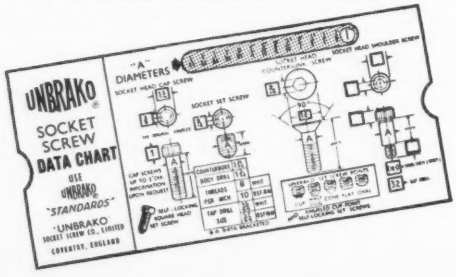

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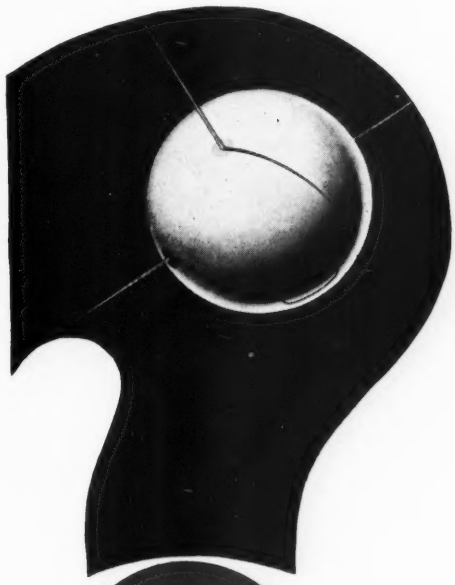

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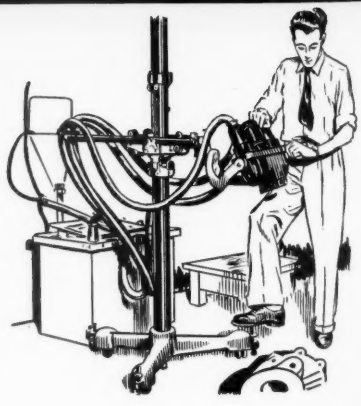

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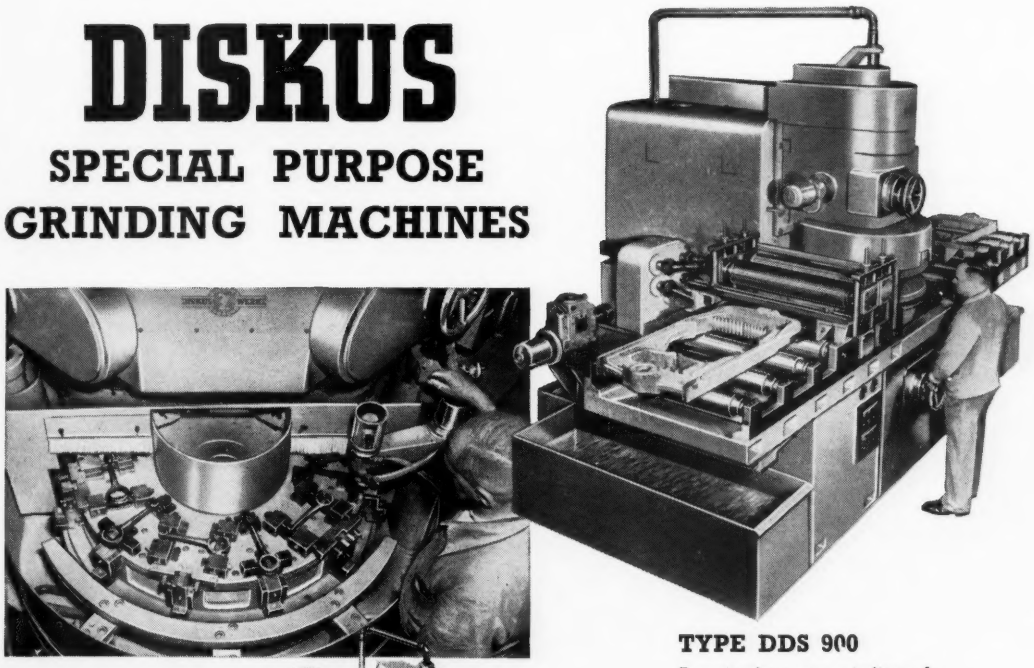

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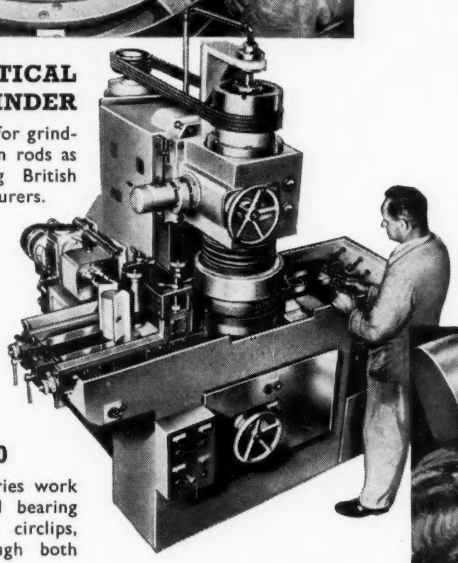

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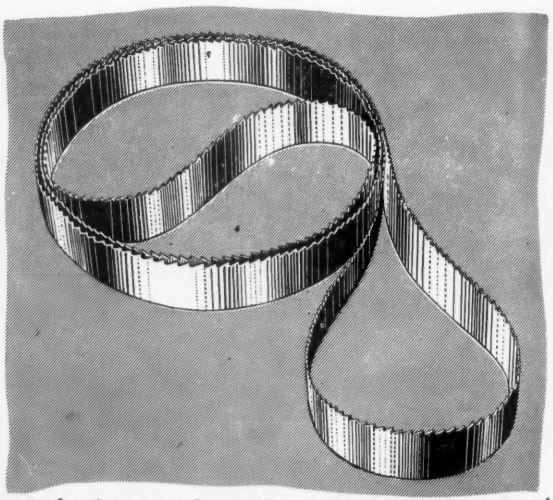

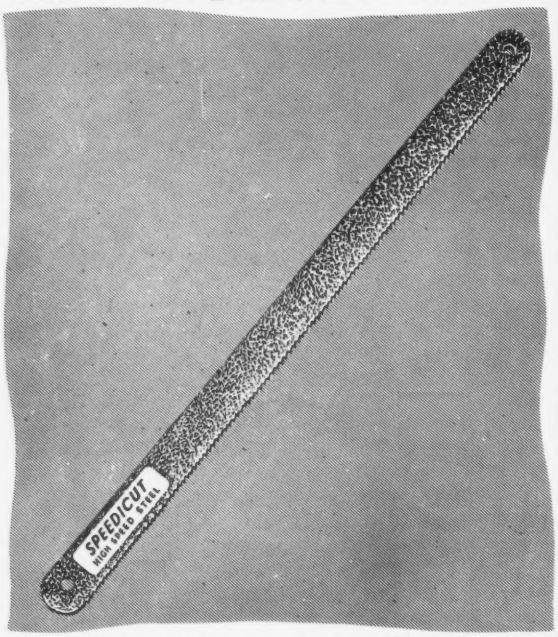

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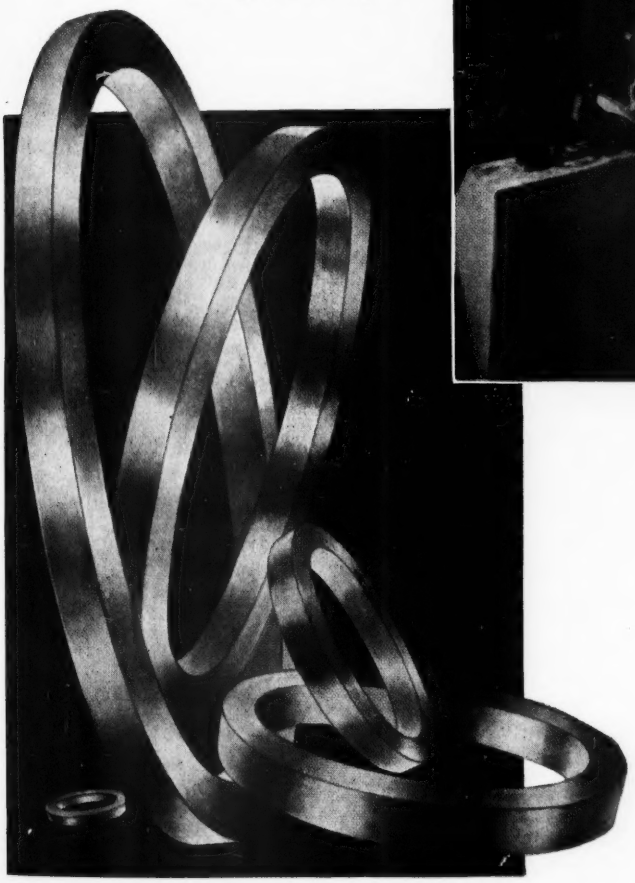

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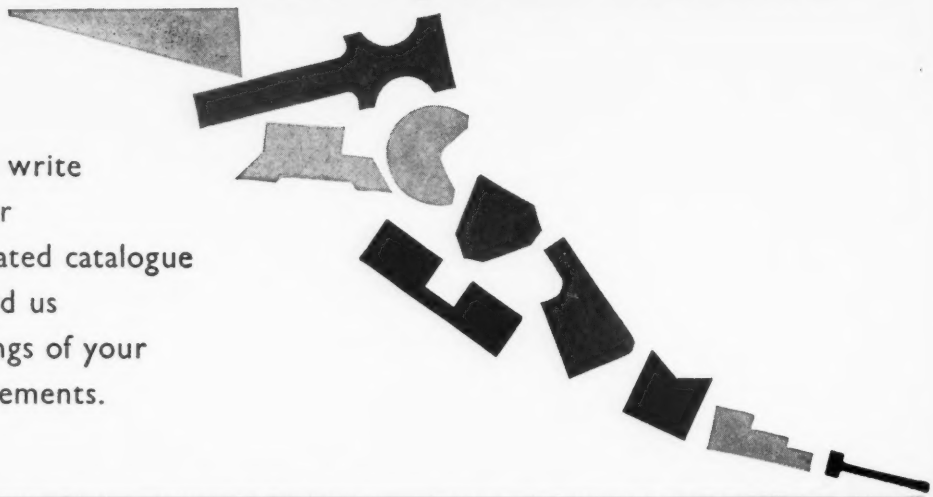

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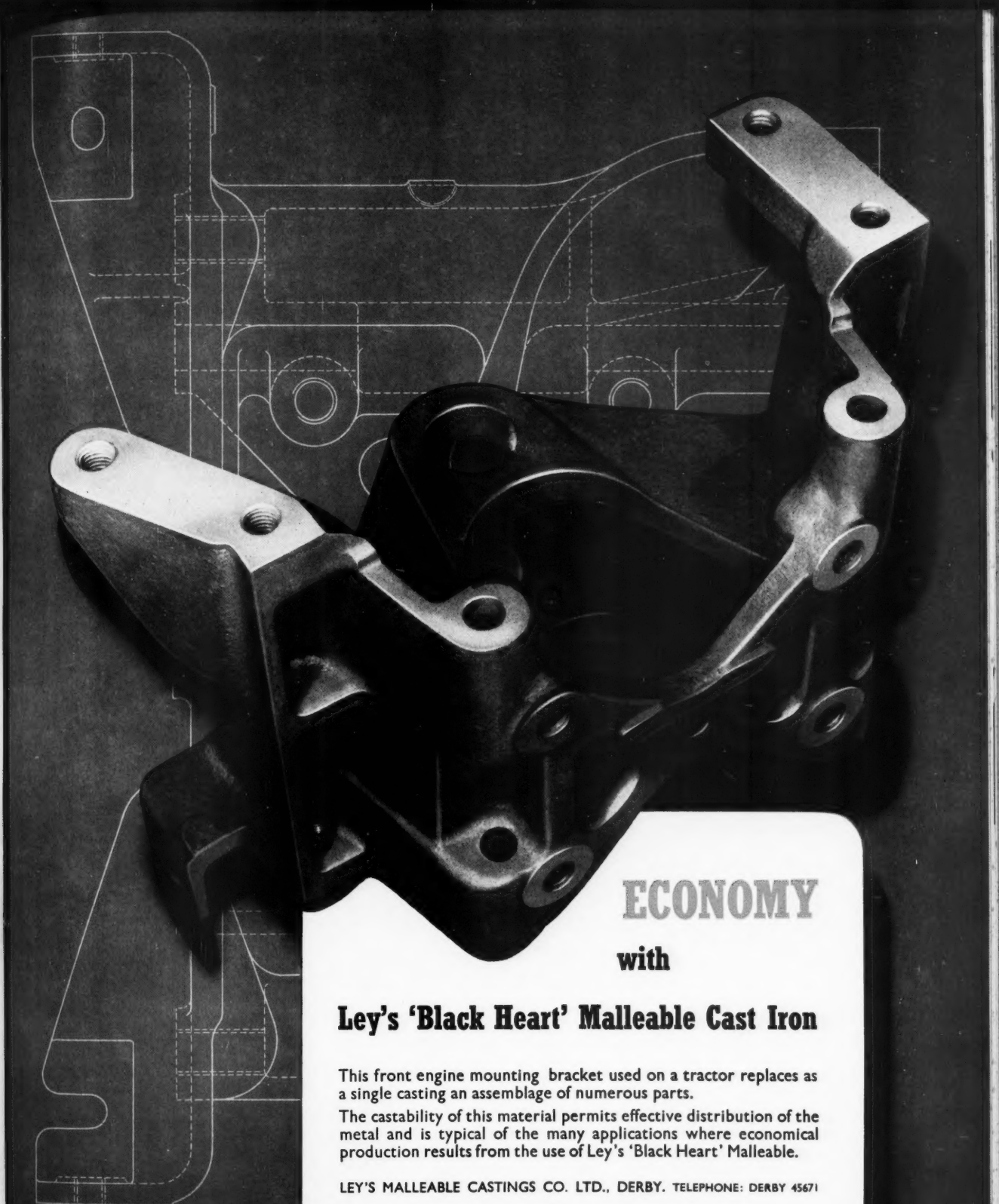

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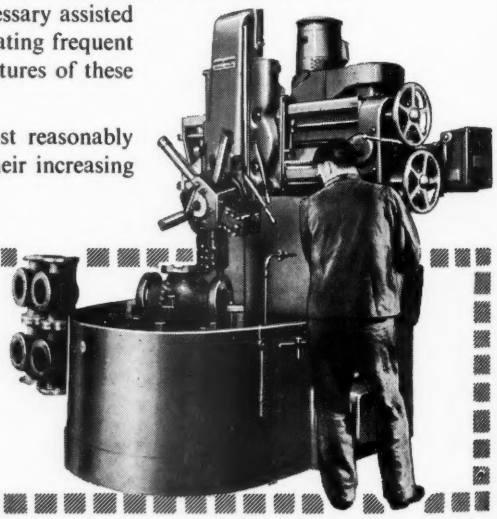

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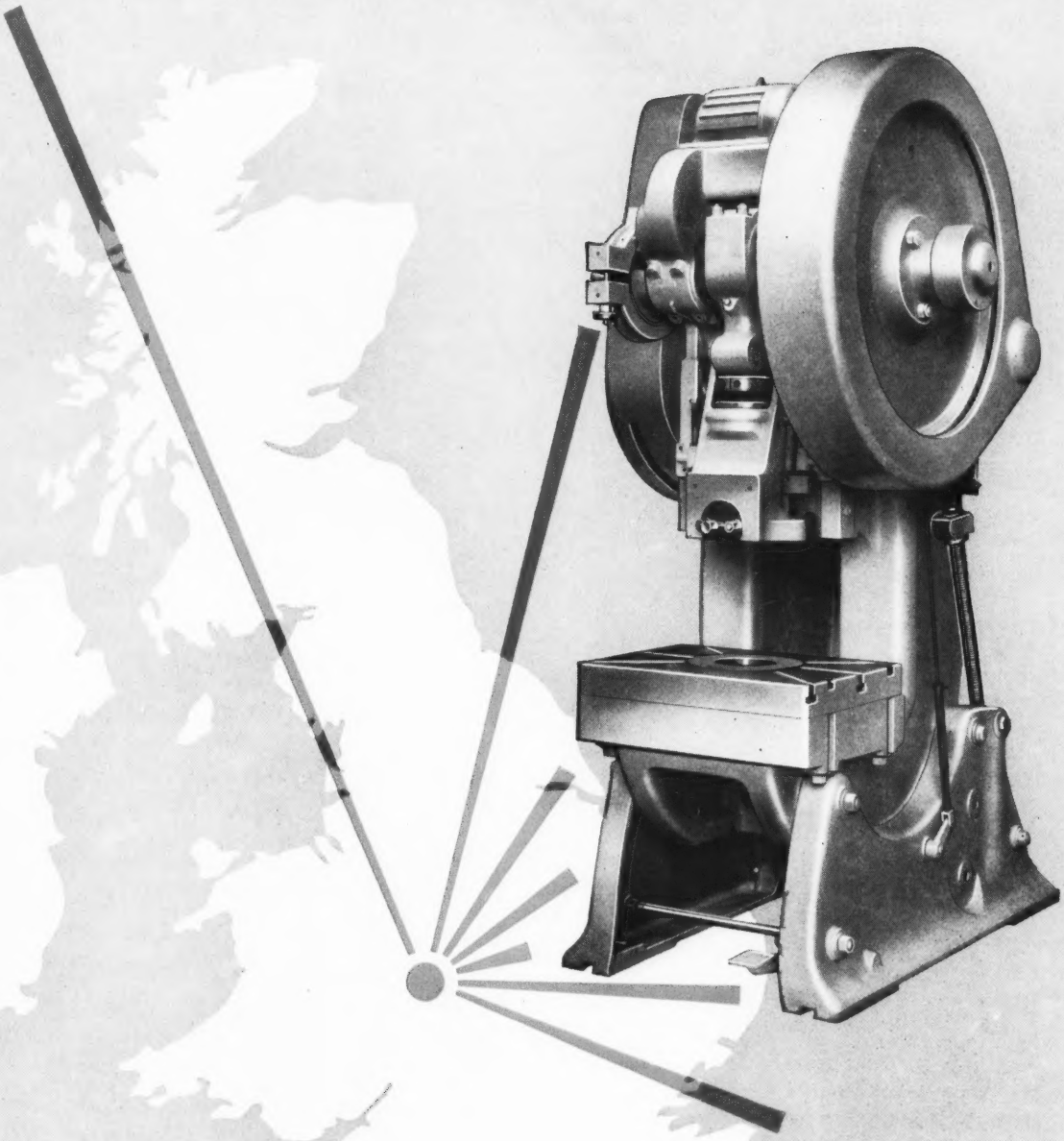

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ABOVE *Abadan Refinery view from the catalytic cracking plant.*

BELOW *The oil pipelines from Agha Jari reach Bandar Mashur.*

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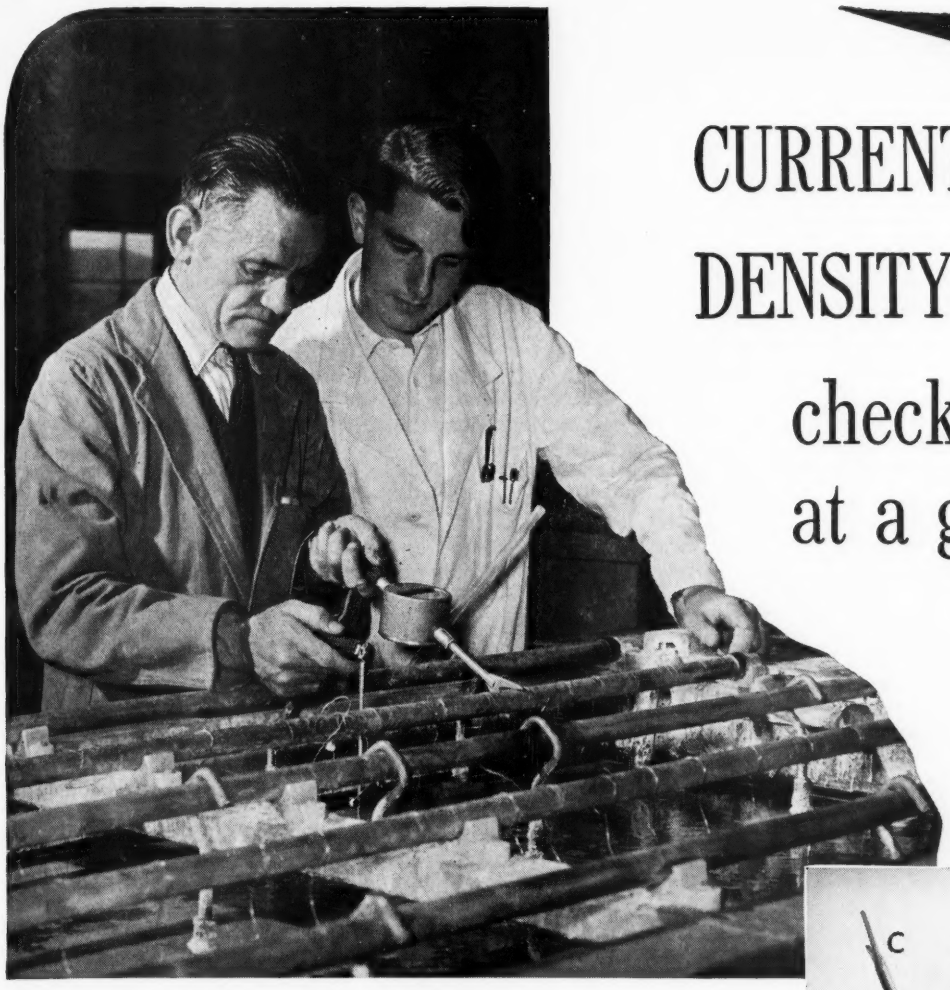
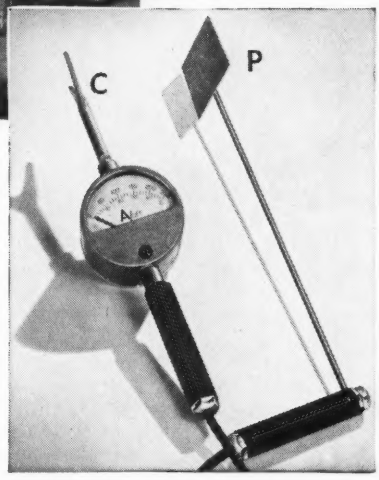


CURRENT DENSITY checked at a glance



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*OPTIMETRIC

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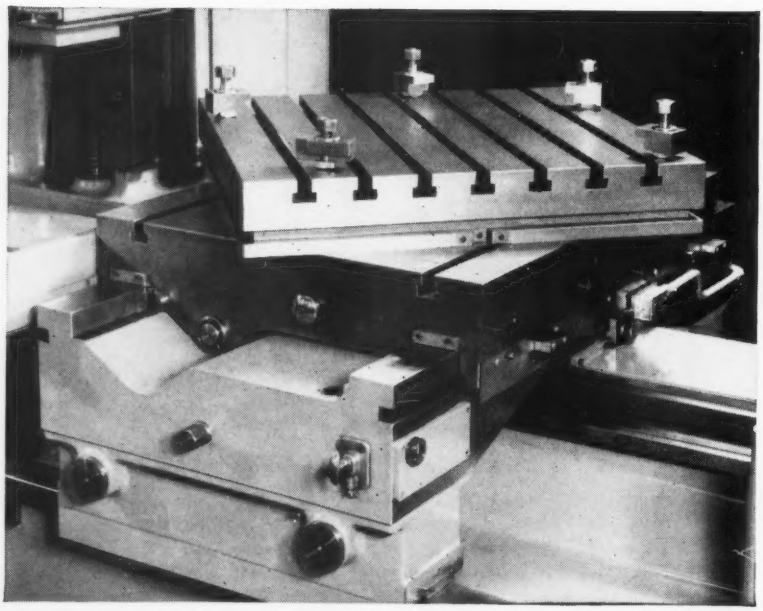
TOOL ROOM BORER



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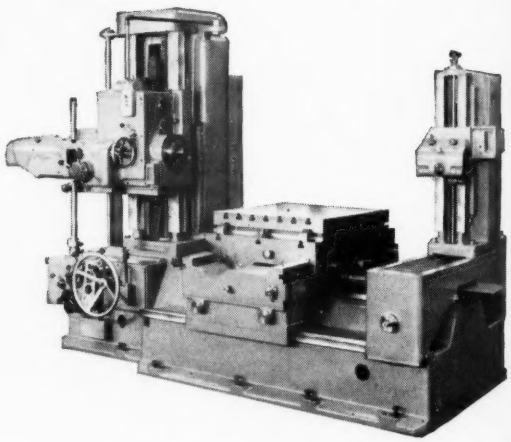

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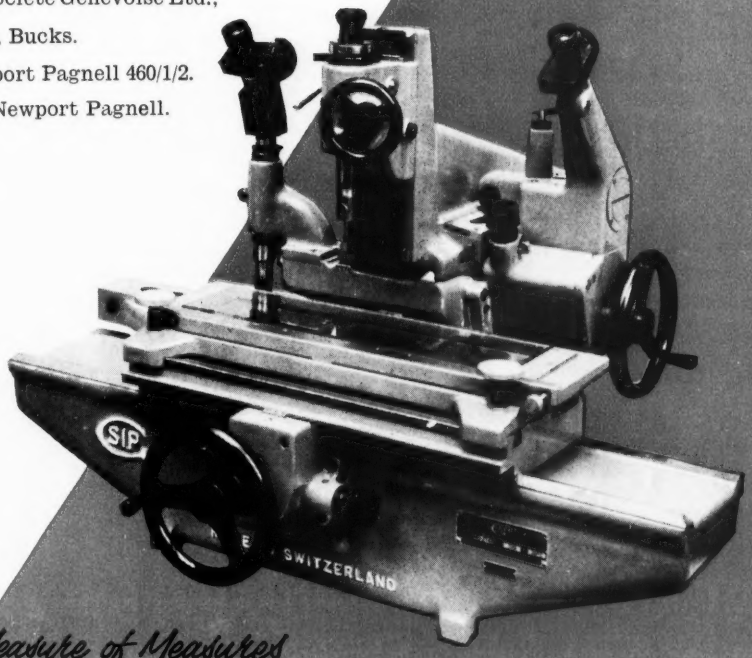

*The Standard Scale is graduated on the same machine and with the same great precision as the fundamental length prototypes supplied by SIP to the National Physical Laboratory (Teddington), the International Office of Weights and Measures (Sèvres) and the National Bureau of Standards (Washington).

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Double helical gear for use at the spade and shovel mill of C. T. Skelton & Co. Ltd., 29 in. dia. × 11 in. face, weight 11 cwt. 2 qr.

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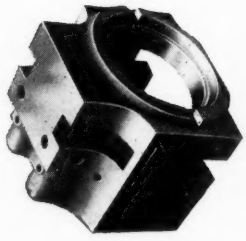

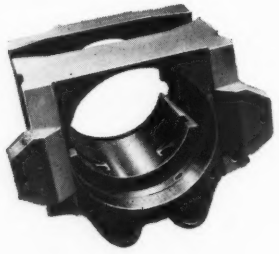

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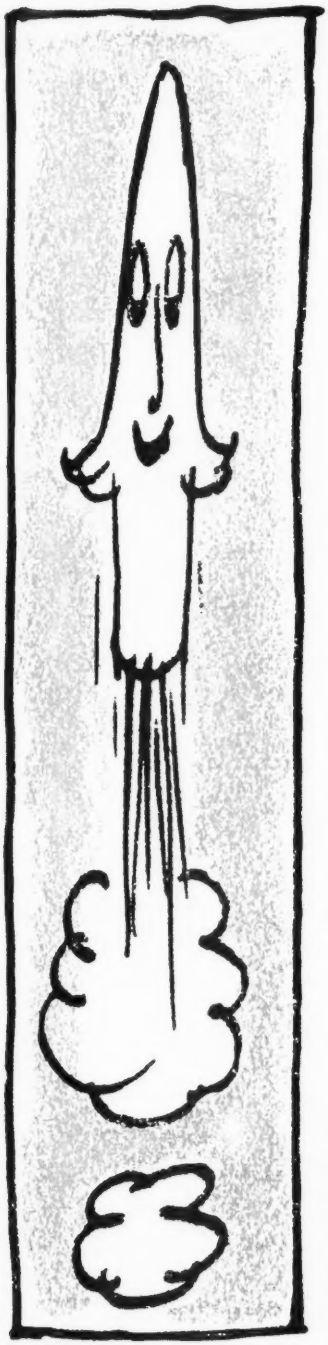

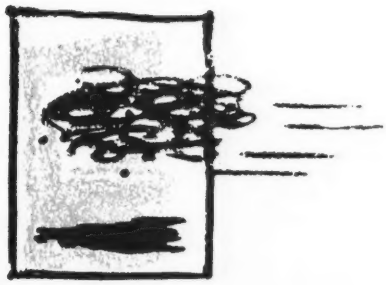

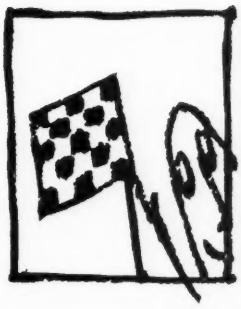

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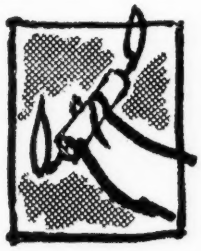

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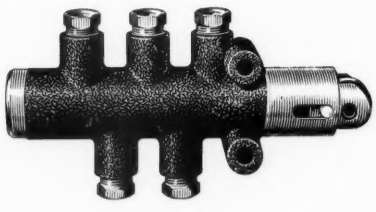

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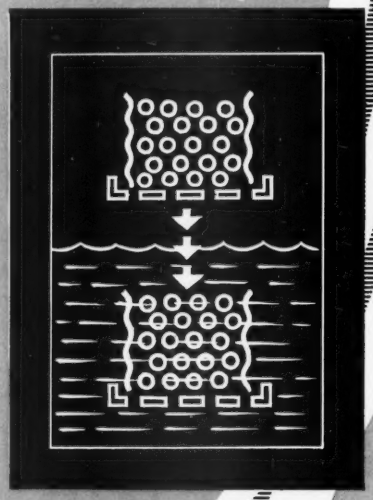

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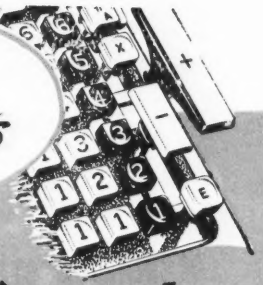

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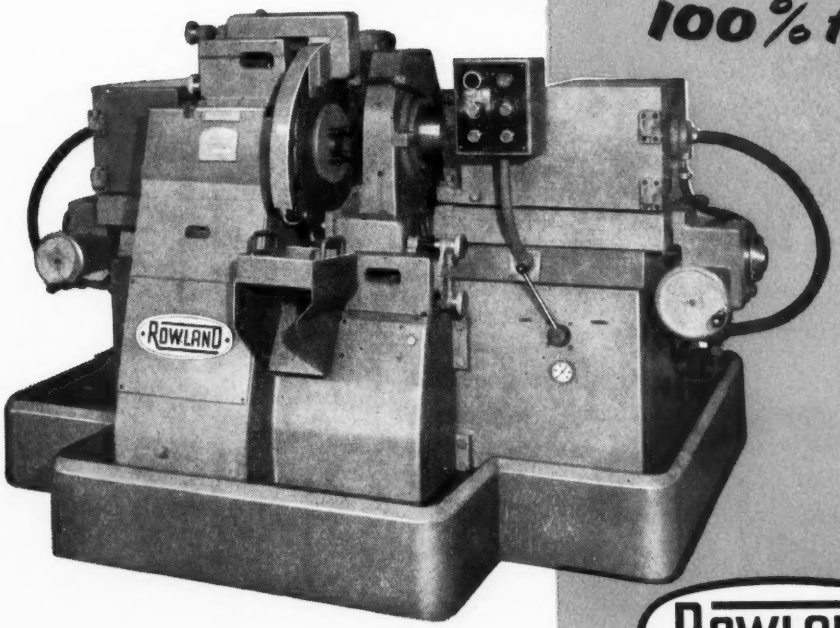

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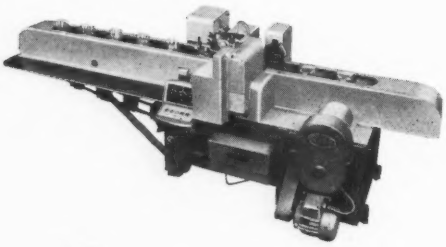

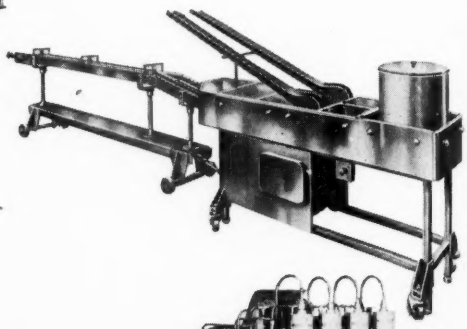

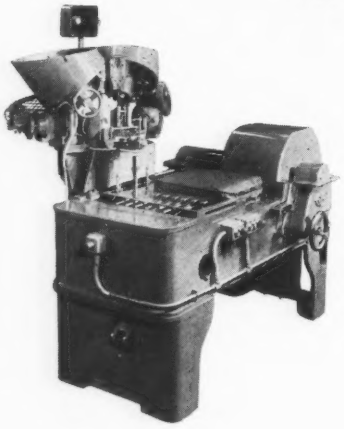

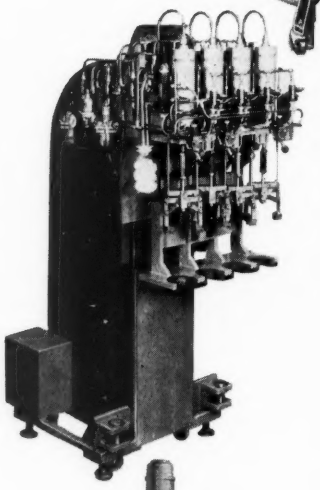

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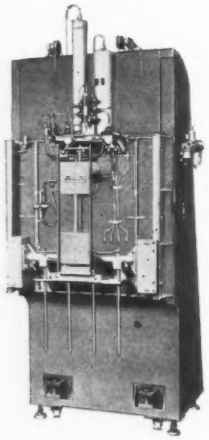

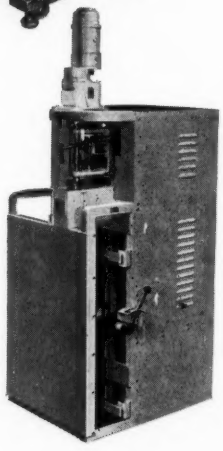

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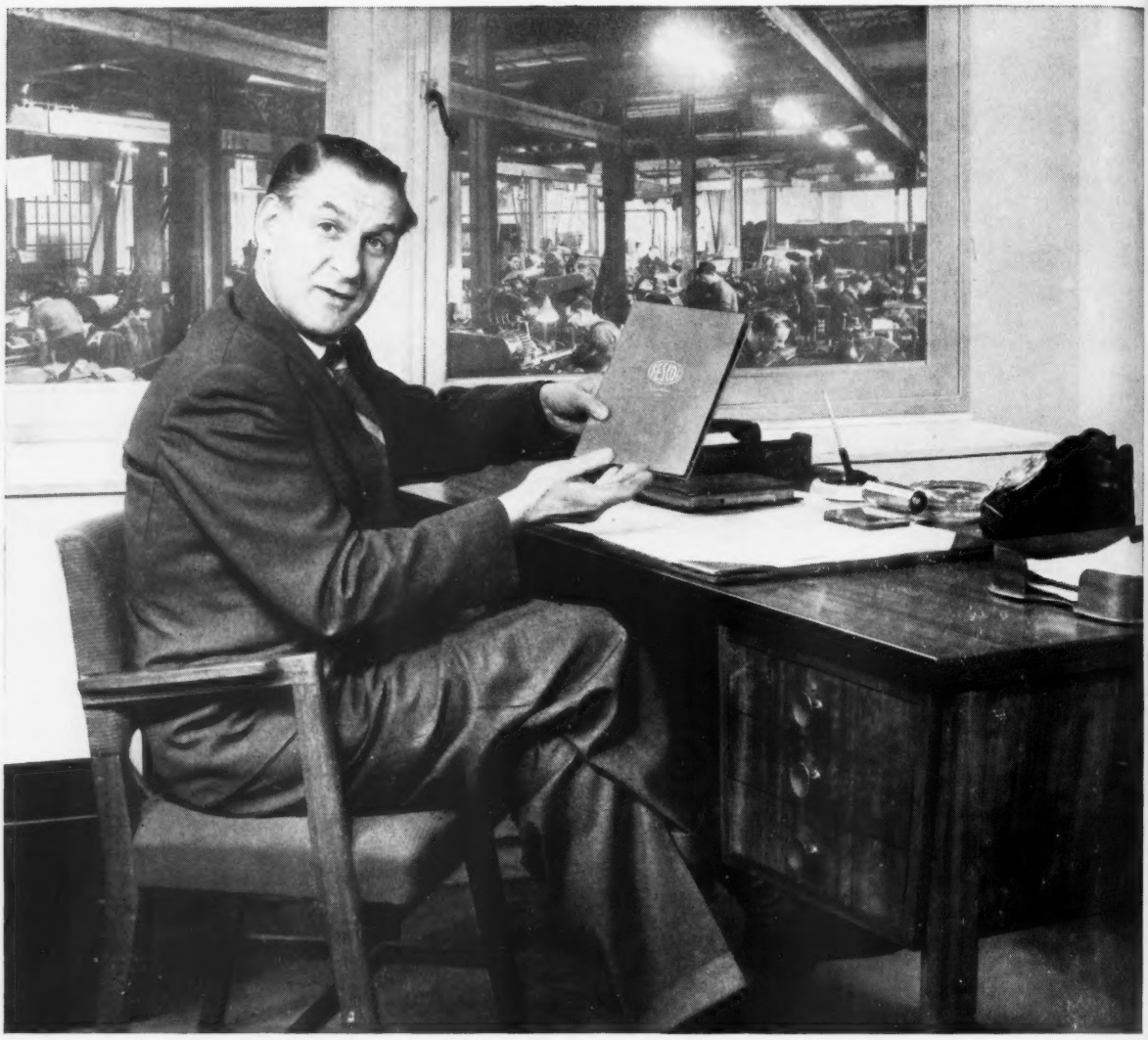

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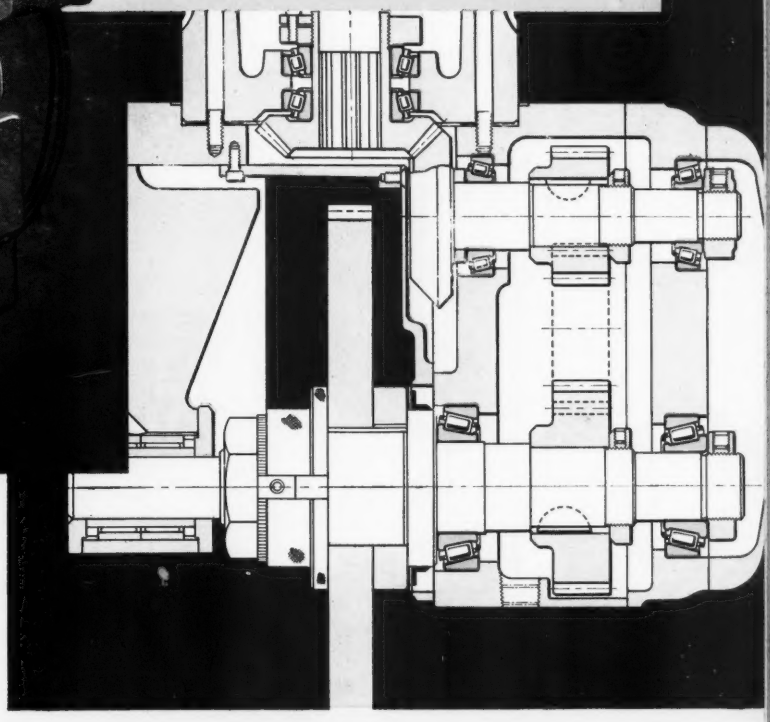
The automatic-loading
CHURCHILL 'RED RING' GEAR SHAVER



The illustration on the left shows the 8 inch model, equipped with a fully automatic loading device. 'Red Ring' gear shavers are also made in 12 inch, 18 inch and 24 inch models.

The line drawing shows the mounting of the cutter spindle on pre-loaded Timken tapered-roller bearings, which gives a positive axial and radial location of great stability. The driving gearing is also carried in Timken bearings.

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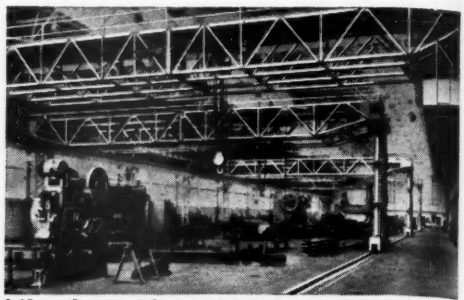
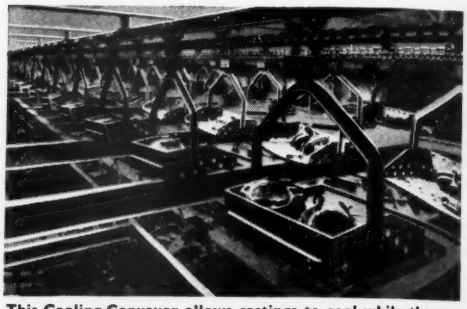
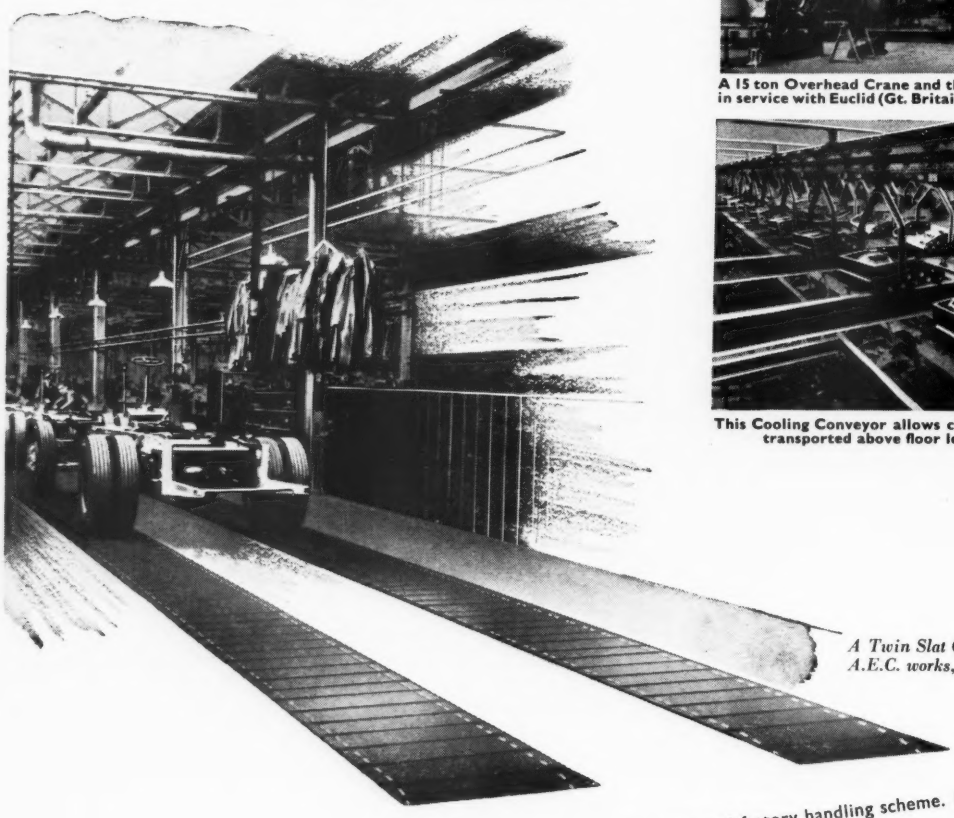


A 15 ton Overhead Crane and three 5 ton semi-Goliath Cranes in service with Euclid (Gt. Britain) Ltd., Newhouse, Lanarkshire



This Cooling Conveyor allows castings to cool while they are transported above floor level to the fettling shop



A Twin Slat Conveyor in operation at the A.E.C. works, Southall, Middlesex

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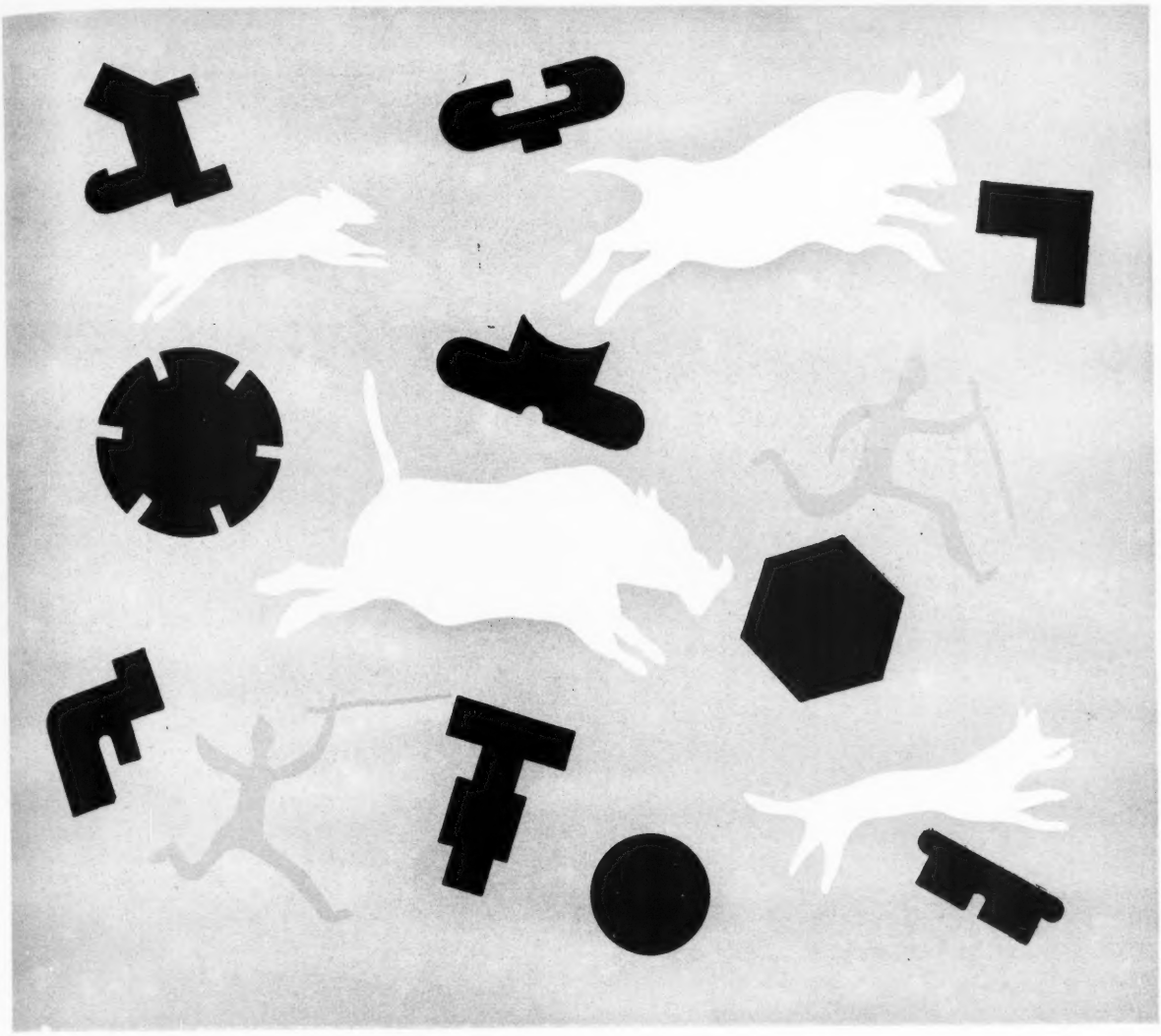

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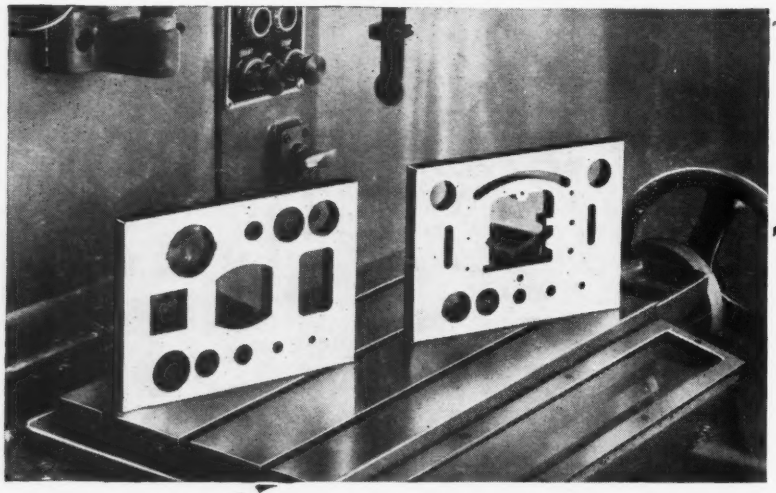

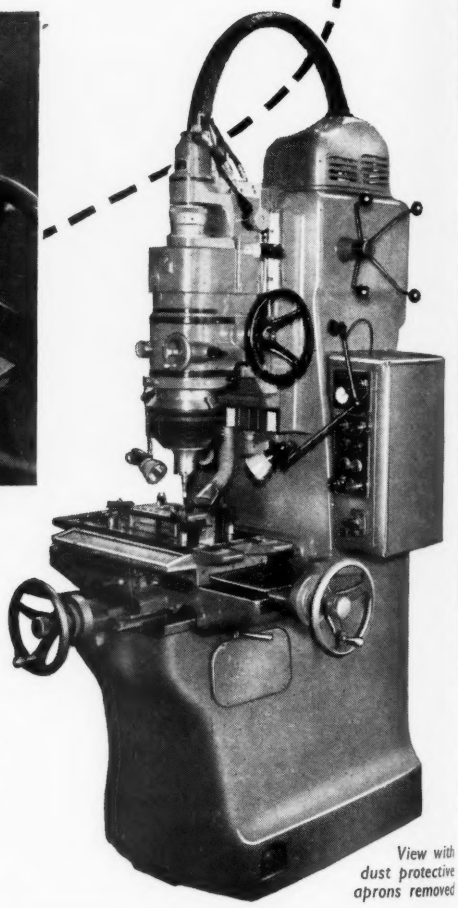

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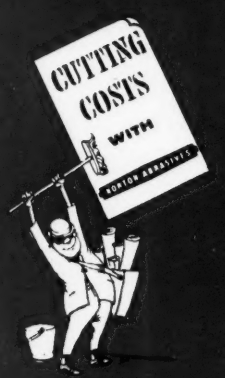

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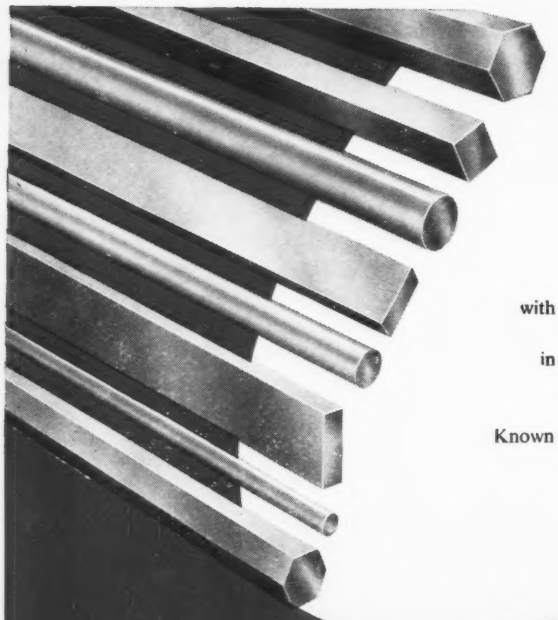

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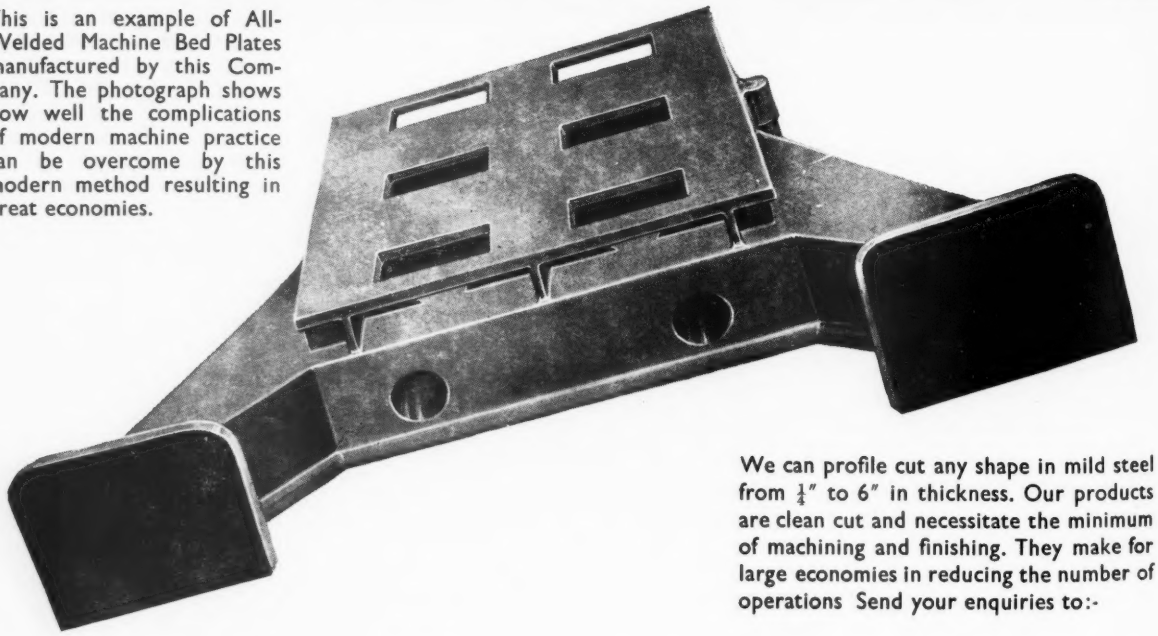

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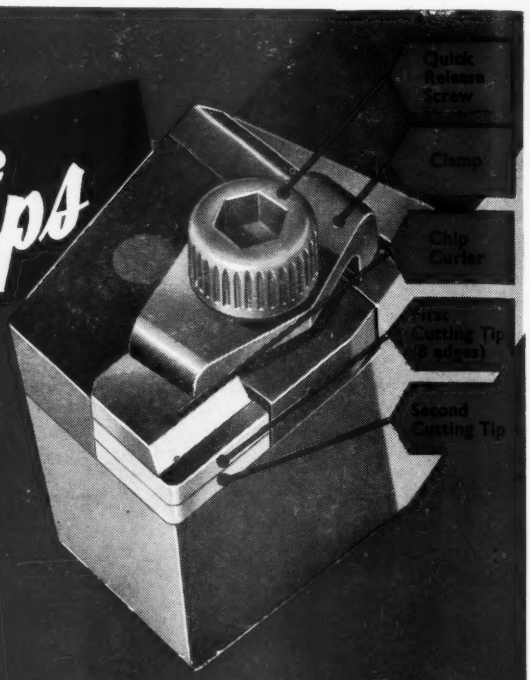

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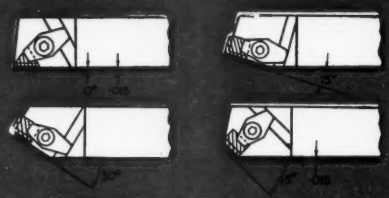

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The Institution of Production Engineers Journal
VOL. 36 NO. 9 SEPTEMBER, 1957

THE CHALLENGE OF THE AGE (3)

by Dr. ING. ERICH MITTELSTEN SCHEID,

Technical Director, Vorwerk & Company, Germany.

In this contribution to the present series of leading articles a German industrialist makes some pertinent comments.

IT is indeed a challenging question that the Institution of Production Engineers has asked. The answer from the German angle may have some unusual points because of the specific situation which the German people had to face after World War II. What was the nature of this situation ?

Production and traffic facilities had been destroyed to a very large extent. A high percentage of living accommodation was in ruins — in some towns up to 60% - 65%. Eastern Germany was put under Russian and Polish administration. Central and Western Germany was split into four zones and the Eastern Zone separated from the Western Zone, politically, under the Russian occupation. Three-quarters of the German population was living in Western Germany, with the addition of 10 million refugees. Two-thirds of the agricultural production capacity remained in Eastern Germany and in the Eastern Zone, and there was virtually no possibility of importing any raw materials for industrial production. There was international resistance — for political reasons — against industrial reconstruction of Western Germany, together with the introduction of a political and economic system of a Communist nature in the Eastern Zone. Finally, communication systems were reduced to a minimum.

Such was the situation German management and labour had to face in 1945. It must be borne in mind that every enterprise was a community in itself in those days, with no connection whatsoever with other enterprises, with a non-existent Government, with non-existent industrial federations or associations, with non-existent trades unions, with a non-operating banking system, and so on. Such a situation might well look like a nightmare to the foreign observer.

Reconstruction by united effort

German managers and workers understood, in those days, that there was but one way out of this disaster : to rebuild the ruins and by a united effort to work their way back into a sound economy and — last but not least — into international recognition. With virtually no outside help, the members of individual enterprises went to work with the slogan : " Help yourself and God will help you ! " in their minds. With the Iron Curtain running right through Germany, Western Germany realised the social challenge of the neighbourhood of Communism as a European problem.

The individual enterprise, no matter whether concerned with industry, agriculture, transportation, banking, distribution, or whatever it may be, operating as a little community, reviewed its resources and means of rebuilding its service to the national economy under the following headings :-

Men
Materials
Machines
Money
Methods
Markets

There were a few men in the beginning, and many more returned from the prisoner-of-war camps. Management had to worry about how to employ them, since it felt a responsibility to do so. There was an extremely limited supply of raw material — management had to decide what the market demanded most urgently which could be made out of the raw material available, and also what machinery was still usable, what could be repaired and put into operation to produce what was needed.

Was there, indeed, a 'market' in the true sense, when there were no transportation facilities, and no banking system in operation ? Germany went through all types of markets from the most primitive, with demand exceeding supply to a large extent, to the most advanced type. The complete lack of equilibrium between money and goods available decreased the value of the Reichsmark on the black market, whereas the legal market with its limited volume of merchandise maintained a more or less normal price level without any Government interference. The foundation was laid in those days for a normal functioning of Western Germany economy on a free enterprise basis, since there was no Government interference or planning, either to give impetus to, or to act as a brake on, business management.

On the other hand, management and labour had to do some basic thinking about the elements of a sound economy and their functional relations and possible priority. They realised that in a sound economy every trade and every profession has its important role to play, much as the various organs of a sound human body have functions to form, if the human being is to remain healthy.

Management's most important task

We feel, in Germany, that the most important task of top management is to preserve a well-balanced equilibrium between the 10 management functions within and beyond the enterprise. These 10 management functions are :-

Enterprise — policy making and organisation
Research and product (or service) development
Planning
Production
Marketing and price-fixing
Finance
Cost accounting and budgetary control
Purchasing and material handling
Personnel
Public relations

It must be stated that the weight and the priority of the various functions varies from enterprise to enterprise according to its nature. An enterprise is bound to fail unless each of the functions is given its proper attention within the framework of the enterprise, and unless care is given to the proper co-ordination and integration of the functions of the various departments. It will be recognised that this idea derives from the principles and philosophy of scientific management as conceived by Frederick Winslow Taylor some 50 years ago.

The results of whole-hearted co-operation

In the human field, it was the experience of the possibilities and importance of true and honest co-operation between management and labour with the enterprise in the first place, on the background of the common fate, which contributed most to the reconstruction of Western Germany. Management understood that there could not be any reconstruction without the co-operation of the workers, whereas the workers (including office staff) understood that management was the only group to rely upon in those days when there was no Government, no industrial federations and no trades unions. So they co-operated wholeheartedly and — much to their surprise — they found that such co-operation was not only possible, but quite successful and enjoyable within reasonable limits. The principle of " delegation of authority and responsibility " more or less automatically was implanted on that spirit of well-balanced co-operation.

The need for the introduction of that principle was urgent, since the group of experienced managers available after World War II was alarmingly small in number and, moreover, they were overloaded with work, responsibility, and the demand for their initiative.

For the same reason, 'management development' as well as 'trade union development' had to be promoted. A wide variety of programmes, mostly built up on American experience and under E.P.A. encouragement, was offered to the public. A co-ordination of such programmes is under way in the "Wuppertaler Kreis", in co-operation with the German productivity centre R.K.W. ((Rationalisierungs-Kuratorium der Deutschen Wirtschaft) and with R.E.F.A. (Verband für Arbeitsstudien). The German Federation of Industry (B.D.I.) sponsored the top management seminars at Baden-Baden, thus supporting a new and successful method. The D.G.B. (Deutscher Gewerkschaftsbund) is running a large number of training programmes with the task of presenting competent trade union representatives under "Betriebsverfassungsgesetz" (Co-determination Law) to industry.

Setting an example

With the Communist system of planned economy as a challenge to the free world immediately next door, Western Germany feels obliged to do its best to set an example of what a free world with free enterprise can accomplish in establishing a well-balanced economy. It feels that production, marketing, transportation and finance must each have its place and play its role to reach the common goal of a sound, economically, politically and socially well-balanced area at the Western side of the Iron Curtain.

We realise that this goal is a long way ahead, but we try constantly to direct our energies towards it.

"Automatic Production – change and control"

CONFERENCE, HARROGATE, 30th June - 3rd July, 1957

Continuing the publication in the Journal of Papers presented at the Conference, this issue contains the following :-

DISCUSSION GROUP A2

"Control and Communication — a Management Concept of Cybernetics" by Miss Joan Woodward, M.A.

DISCUSSION GROUP B3

"Scheduling for Batch Production" by Dr. S. Eilon, A.M.I.Prod.E.

DISCUSSION GROUP B4

"Simplification and Standardisation for Automation" by E. G. Brisch, M.I.Mech.E., M.I.Prod.E., F.R.S.A. and R. S. Geoghegan, T.D., M.I.Mech.E., M.I.Prod.E., F.I.W.M.

DISCUSSION GROUP D4

"Master and Man — a New Look at an Age-old Relationship" by E. C. Gordon England, F.R.Ae.S., F.I.M.T., M.I.Prod.E., F.I.I.A.

"CONTROL AND COMMUNICATION – A MANAGEMENT CONCEPT OF CYBERNETICS"

by Miss JOAN WOODWARD, M.A.

Miss Woodward is Director of Research at the South East Essex Technical College. In 1949/51, she was in the Department of Social Science at the University of Liverpool, in charge of investigations which led to the publication of a book entitled "The Dock Worker", published by the Liverpool University Press.

In 1951, Miss Woodward was responsible for research in hospital administration which was carried out in the Central Wirral Hospitals, and a report was published by the Institute of Hospital Administrators, under the title "Employment Relations in a Group of Hospitals".

She has also spent some time in industry, being particularly concerned with textiles, light engineering and explosives, and in the Labour Division of the Ministry of Supply.

In private life, Miss Woodward is the wife of Mr. L. T. Blakeman, Industrial Relations Manager at the Ford Motor Company.

THE first point I wish to make is that I am not a cybernetician and am not going to explain what cybernetics is all about. This has already been done far more expertly than I could do it by Mr. Stafford Beer, in the Paper he presented as the 1956 George Bray Memorial Lecture[1]. The title of this Paper, "Control and Communication — A Management Concept of Cybernetics", had already been fixed and published before I was asked to write it and my agreement was conditional upon my being allowed to begin by making this disclaimer.

It would have been more appropriate to give this Paper some such title as that of the Conference itself, with perhaps a sub-title "The Effect of Cybernetics and Advanced Technology upon our Concept of Management". The problem I am going to discuss is the relationship between technical change and management structure. To what extent are the techniques of operational research and the introduction of the wide variety of mechanical, electrical and electronic devices included in the definition of automation given in the publication of the Department of Scientific and Industrial Research[2], likely to modify not only the organisational structure of industrial firms, but also the attitudes and behaviour of the managers and supervisors they employ and the human relations within them?

The Paper is based on the findings of a research project undertaken at the South East Essex Technical College between 1953 and 1956, sponsored by the Department of Scientific and Industrial Research/ Medical Research Council Joint Committee on

1. "The Scope for Operational Research in Industry" by Stafford Beer, published by the Institution of Production Engineers, 1957.
2. "Automation", Report of the Department of Scientific and Industrial Research, published H.M.S.O., 1956, Chapter 7.

Human Relations, and financed from Counterpart funds derived from Economic Aid. A full report of this research will, it is hoped, be published in book form in the near future under the title "Management Organisation and Technical Change".

Theory of management

Our body of knowledge about management organisation and behaviour comes from two sources. First, we have management theory which owes little to systematic empirical research. Most of the principles of management have been derived by practitioners, either by management consultants or by executives themselves from their successful field experience in industry and commerce, the Armed Forces or the Civil Service. Although some tend to give these principles the weight of scientific laws, they are really little more than administrative expedients, closely associated with the personalities of individuals. They have been found to work well in certain circumstances, but have never been tested in any systematic way.

The social sciences

The second source is the social sciences. When the social scientists began to enter the field of industry they tended to think in psychological terms and to ignore organisational principles. They were more interested in informal than in formal structure and tried to explain what happened in the factory entirely in terms of inter-personal relationships and group attitudes and behaviour.

These two approaches to management studies developed independently, each being suspicious of and hostile to the other. They had, however, one thing in common, in that they both tended to ignore what Mr. Eric Trist of the Tavistock Institute of Human Relations has referred to as the "technical dimension". In the past, management theorists have tried to develop principles of administration proper for any type of production, and social scientists have assumed the strains and stresses arising from industrial life are common to all types of manufacturing firms. Mr. Stafford Beer, too, in the Paper referred to above, sees operational research as offering to management a set of powerful new tools, and implicit in this definition is a static concept of management aided but not changed by new techniques.

Recent developments in industry challenge the management theorists and the social scientists alike. Information is accumulating, although as yet much of it is anecdotal in character and comes from the United States, indicating that automation and other technological changes are often associated with considerable disturbance in the management system of the firm concerned. There is a chain relationship of the kind experienced by the nursery rhyme character who tried to bring the pig home from market. New tools begin to change the task and the new task begins to change both the organisation of the task and the qualities required to carry it out successfully. For example, the qualities required of the foreman on the motor-car assembly line appear to be so different from those of the man in charge of the transfer line for cylinder blocks as to make such expressions as "The Art of Foremanship", used so glibly in the past, almost meaningless. From the information available so far two interesting pointers emerge: the first is that the management organisation and qualities required in the factory undergoing a period of radical change are different from those required in the stable firm, and the second is that the pattern of organisation required in the technically advanced firm is different from that previously recommended by management theorists.

The project in four stages

The project was carried out in four distinct stages. Firstly, a geographical area was defined covering 120 square miles of East London and Essex, and every manufacturing firm in that area was located and contracted: in all, 203 firms. It is interesting to compare the size distribution of these firms with that given by the Ministry of Labour for the country as a whole. The interesting thing is that there are more large firms; 9% of the firms covered employed a thousand people or more as against 1.7% for the country as a whole. Secondly, the research workers approached the firms employing 100 people or more, 110 in all, and asked if they were prepared to co-operate by providing the College with information about their objectives and background history, and about the way in which they were organised and operated. 100 firms (91%) were willing to do this and the following information was collected:

1. History, background, and objectives of the firm.
2. Description of manufacturing processes and methods.
3. Organisation Chart.
4. Cost Analysis.
5. Labour Analysis, i.e. ratios of
   (a) Direct production workers to total personnel.
   (b) Maintenance to direct production.
   (c) Clerical and administrative to hourly paid.
   (d) Management supervision to total personnel.
   (e) First line supervision to direct production.
6. The degree to which the functional theory of management was manifest in structure.
   Organisation of
   (a) Sales function.
   (b) Research and Development.
   (c) Personnel function.
   (d) Inspection.
   (e) Maintenance services.
   (f) Supply function.
7. Procedures used in production control, planning, programming, work study, etc.
8. Qualifications — training of managers and supervisory staff; recruitment and promotion policy.

This survey revealed considerable differences between the firms covered. Fourteen different industries were represented and firms ranged in size from 100 to over 30,000. There were also considerable variations in organisational structure. The number of distinct levels in the hierarchy from the operators to the Board ranged from two to 12. The number of people directly responsible to the chief executive ranged from two to 19 and the span of control at the lowest echelon from seven to 90. Thirty-five firms were organised on what was essentially a line pattern; surprisingly two were found to be organised functionally, almost exactly as recommended by Taylor 50 years ago, while the remainder conformed in a greater or lesser degree to the line and staff pattern. Moreover, firms varied in the extent to which a knowledge and acceptance of the principles of management were implicit in their organisational structure.

It was extremely difficult to trace any uniformities among the divergences. Differences were not related as closely to size or to type of industry as might have been expected. Moreover, conformity with the principles of management did not always appear to be associated with business success. Administrative efficiency is, of course, extremely difficult to measure and the assessment made by the research workers was necessarily impressionistic. They compared firms one with another on the basis of various criteria; these included such obvious factors as profitability, market standing, prospects of survival and rate of development, and also more subjective factors such as the quality, attitudes and behaviour of managerial and supervisory staff, the extent to which a firm was able to offer a satisfactory career to those it employed and local reputation.

The test of complexity

The final analysis of the data was made grading firms according to the degree of complexity of the techniques of production in operation in them; the test of complexity being the extent to which effective control could be exercised over the physical limitations of production. At the bottom of the scale were the firms making simple unit articles such as bespoke suits, and at the top were the automatically controlled distillation plants. The technical demands of the manufacturing process varied to some extent from firm to firm, creating in each case a unique socio-technical situation. Moreover, there were firms in which the use of operational research techniques had enabled management to exercise more effective control over the physical limitations of production than was exercised in other firms where the manufacturing processes were similar. Nevertheless, firms could be grouped together on the basis of their production systems and the organisational structure of firms in the different groups could be compared.

Eighty-nine of the firms covered could be classified into the following groups. In the other, 11 production systems were mixed or undergoing radical change:

The manufacture of simple unit articles.
The manufacture of technically complex unit articles and large equipments.
Small batch production.
Large batch production.
Mass production.
Process production of batches.
Flow process production of liquids, gases, crystalline substances and solid shapes.
Process production combined with the preparation of a product for sale by large batch or mass production methods.

These could be regrouped into three main categories, viz., unique article and small batch production; large batch and mass production; and process production. It was interesting to find that although we tend to think of mass production as being the typical system of our industrial society, only 31% of the firms in the area covered came into this category.

The pattern emerges

When the firms included in the survey were grouped together in this way, the vast mass of information collected by the research workers about organisational structure began to form a pattern. There were differences in organisational structure between firms in the same group; these differences related to the history and background of the firms concerned, and to the personalities of those holding key positions in them. These differences were not, however, of the same magnitude as the differences between groups; personality appears to influence structure only within limits set by technological considerations. Different production systems present characteristic situational demands and these demands are successfully met by different organisation and structural expedients. Moreover, this analysis of the research data revealed that successful firms did after all have something in common; their organisational structure approximated to the median of the group in which they had been placed. When the mass production and large batch production firms were examined separately, a relationship was revealed between conformity with the principles of management and administrative efficiency. This might have been expected, for management theory has been largely developed from experience in this kind of industry. Outside this limited range of technology there was, however, no such relationship. Some of the more obvious differences in pattern between the three main production groups are shown in the Tables at the end of this Paper.

There appears too, to be a relationship between certain characteristics of organisational structure and technological advance; this is in some but not all cases a direct or progressive relationship. We find, for example, that the ratios of managerial and supervisory staff to total personnel, of administrative and clerical staff to hourly paid operators, of indirect to direct labour, and of graduates to unqualified supervision all do increase as technology advances. In other respects, however, firms at the extremes of the technical scale resemble each other, while both

groups differ from the groups in the middle of the scale. Organisation appears to be more flexible at the extremes and more rigid in the middle. Further more, the proportion of written to verbal communication between managers increases to a point about three-quarters of the way up the technical scale and then decreases rapidly.

A similar pattern emerges in respect of specialisation and functional control. The line staff pattern is more developed in large batch and mass production, and less developed in unique article and process production. As a result, the technical competence of the line supervisors themselves is more important at the extremes of the scale than in the middle. Moreover, although production control becomes increasingly important as technology advances, the administration of production and the actual supervision of production operations first separated by Taylor and widest apart in large batch and mass production, appear to become increasingly reintegrated as technology advances beyond this point.

The size of the span of control of the first line supervisor drops sharply in process and automatic production; so, too, does the proportion of the total costs that have to be allocated to the payment of wages and salaries. Responsibility appears to be delegated to a far greater extent in firms in this group than it is in mass production or unique article production firms. A limited amount of information about attitudes and behaviour was obtained during the course of the survey. Many of the people who gave the research workers factual data about the organisation and operation of their firms also expressed opinions about how this organisation worked, and discussed some of the problems associated with it. This information suggested that not only organisational structure, but also the general atmosphere and the quality of human relationships were influenced by technical demands.

Relieving the pressure

Here again the situation was similar at the extremes of the technical scale. Pressure on people at all levels of the industrial hierarchy appears to increase as technology advances, until it reaches its maximum in mass production of the assembly line type, then it decreases rapidly. This relaxation, together with the breaking down of the labour force into very much smaller groups and the fact that the process firm is less concerned with labour economy because of its comparatively low labour costs, makes the industrial relations situation very much easier generally. This implies that automation and other forms of advanced technology, while they will give rise to the human and social problems inevitably associated with change, may in the long run solve many of our current industrial relations problems. Mr. Norbert Wiener, in calling his book "The Human Use of Human Beings" *, was thinking of advanced methods of production as releasing human beings from the drudgery of manual and mechanical tasks. What is probably equally important is that they may relieve both operators and managers alike from the pressure which inevitably arises from mass production of the older type, and from the tensions in inter-personal relationships which are inevitably associated with it.

Having completed the analysis of the information they had collected together, the research workers felt confident that it had demonstrated adequately the existence of a link between technology and management organisation and problems. It had, moreover, thrown considerable doubt upon the assumption that there are principles of administration which are proper for any type of production, for each system of production appears to have an associated organisational pattern and its own set of organisational problems. The organisational patterns that emerged were, however, rather like the diagrams of the skeleton in the First Aid Manual; they provided a framework but offered no satisfactory explanation of how the body functioned.

The next step, therefore, was to try and find out more about how and why this link occurs. What are the situational demands arising from the different technologies, and is it possible to trace causal relationships between each system of production and its associated organisational pattern? In order to do this the research workers began the third phase of the research. Twenty firms were selected at intervals in the technological scale and studied in more detail. The fourth and final stage of the research was the undertaking of three very detailed case studies in which production systems were mixed or changing.

In each firm studied, the research workers began with a systematic examination of the manufacturing process itself, analysing the various tasks contributing to the achievement of the firm's overall objectives. They then went on to study the number and nature of the management decisions taken and the level in the organisation at which different decisions were made. Finally, they analysed the kind of co-operation required between the various members of the management team and the nature of the control exercised at the various levels in the organisational hierarchy. This enabled them to define with a reasonable degree of preciseness the situational demands arising from the manufacturing processes in operation in the firms concerned. Having defined situational demands, they then began to consider the organisational characteristics and administrative expedients likely to be effective in meeting them. On the basis of the conclusions reached they then tried to assess the appropriateness of the firm's organisational structure. In this analysis of situational demands could be found explanations of many of the differences revealed by the background survey, between firms in different production groups.

The most detailed of these case studies took a research worker six months to complete and as might be imagined, a considerable amount of information was collected. All that it is possible to do in the time

* Norbert Wiener "The Human Use of Human Beings", Eyre & Spottiswoode, London, 1950.

available here is to touch very briefly on some of the more interesting ideas that emerged relating to the impact of advanced technology on organisational structure, in particular, those which relate to problems of communication and control. It is important to emphasise at this point, however, that the words "communication" and "control" are used in their widest sense, implying processes of management, rather than in the narrower sense in which they are used by cyberneticians. When Mr. Norbert Wiener defined cybernetics as "the science of communication and control in living animals and machines", he was referring specifically to the response of organisms to various stimuli.

The pattern of communication

Considering communication and control as management processes, however, the first and most obvious conclusion formed by the research workers was that the pattern of communication established inside a manufacturing firm is inevitably determined by technical demands. The methods of manufacture determine the extent and nature of the co-operation required between those responsible for the various functions of managment, and the communication pattern must be effective in bringing this co-operation about.

For example, if we take the simplest division of functions, the division between development and research, production itself, and marketing, we find that the closeness with which these functions must be integrated and their chronological sequence varies from one production system to another. In the manufacture of unique articles, the manufacturing process begins with marketing. Marketing in this type of industry is the securing of an order: the job of the salesman being to convince the customer that his firm is capable of producing the article required. The order is followed by the development of the product; often this is done in close collaboration not only with the salesman but also with the customer himself. The final stage is production itself. All three functions must co-operate with each other on a day-to-day working basis; a production hold-up such as the failure of a raw material supply and the subsequent decision to substitute may involve not only the sales and development departments, but the customer, too. In such a situation what is needed is a flexible structure characterised by verbal as opposed to written communication; short lines of control and well developed bridge communications. As the survey showed, this was the pattern of organisation found in the most successful unique article firms.

In mass production the situation is very different; a day-to-day working relationship between product development and production might have disastrous results. The bringing of a new product into production is a deliberate process; the decision being taken at a high level. Thus, the basic functions of management can operate independently. What is required, however, are mechanisms for bringing together on occasion and for specific purposes, functions which are normally separated. For example, development and production have to be brought together when a new product is brought into large-scale production, or again, those responsible for marketing must be able to communicate to those responsible for development the opinions and desires of the customers they deal with.

In process production the situation is different again. Here the product and the process are closely related, new products can be created by a change in process. Thus the marketing function fits in between development and production, its main task being to create a market for the newly discovered product. Here again, organisation needs to be more flexible and the functions more closely integrated.

Even this very simple analysis of basic functions indicates that each production system requires a different kind of communication pattern; the phrase "co-operation between the functions of management" means different things in different settings. This becomes even more evident as functions are analysed in more detail. In recent years we have heard about the importance of a good system of communications in industry. This research emphasised that communications systems cannot be good or bad in themselves. They are good insofar as they provide people with the information they need at the time they need it, and bring about co-operation as and when it is most required. The importance of this is that where advanced technology or techniques of operational research bring about fundamental changes in the production system, the nature of the co-operation required between the functions of management will change also, as will the pattern of communications inside the firm.

Situational demands

The research workers found that the situational demands of the manufacturing process determine not only the pattern of communications required, but also the nature of the management decisions that have to be taken. As technology advances and increasing use is made of operational research techniques, decision making becomes an increasingly rational process. The number of immeasurable variables that have to be taken into consideration become progressively less and as the consequences of choosing one course of action out of several alternatives can be foreseen more exactly, top management hunches are required to operate over an ever-narrowing field. This is probably the most important single effect of advancing technology on management structure and it has far-reaching implications.

In the first place, it is doubtful whether in the industry of the future it will be possible to make sound administrative decisions except on a basis of technical competence. Those engaged in operational research may be the back-room boys who feed the administrators with information and ideas, but the administrators they serve must at least be able to appreciate the significance of their work. In the past we have tended to assume not only that there are principles of management proper to every type of production, but also that an able administrator

can operate successfully in a number of different spheres and that administrative skill can be dissociated from technical competence. Many of the high level industrial appointments made in this country since the end of the War, particularly in the nationalised industries, have been based on this assumption. If, however, as the evidence of this research tends to suggest, sound decisions about the objectives and operation of a technically advanced firm can only be made by those with a knowledge and appreciation of its technology, wide implications follow for the selection and training of managers. The aim must be to develop administrative skill upon a basis of technical knowledge.

The importance of delegation

If, however, we assume that the managerial and supervisory group in a process production or automatic production factory have the technical competence required, this increasing rationality in the decision making process means that any two individuals with similar qualifications and background training, and with a knowledge of the same set of facts, are likely to make the same decisions up to the point at which they become involved in value judgments. This will greatly facilitate the delegation of the responsibility for decision making down the management hierarchy. One of the major obstacles to delegation is the insecurity of the individuals who possess the power to delegate. While therefore personality is important here, environment factors also influence the situation. If those delegating authority can be confident that over a wide field their subordinates will make the same sort of decisions as they would make themselves, they can delegate more confidently. As a result, the lower levels of management are likely to obtain a greater amount of satisfaction from their jobs.

The decisions associated with process and automatic production are of two distinct kinds; they are either policy decisions, which because of the inflexibility of production facilities, inevitably commit the firm concerned for a considerable period into the future, or problem-solving decisions, which are normally associated with operational difficulties, and which are in most cases of great urgency. Because the situational demands of process industry encourage delegation, these problem-solving decisions can be made very close to the point at which the crisis occurs. Policy decisions, because of their magnitude, on the other hand, tend to be made at Board level.

We find, therefore, that the chief executive of the process firm and his top level managers make relatively few decisions themselves in comparison with their counterparts in unique article production and mass production firms. This leaves the chief executive freer and enables him to spend more of his time on the ritual duties so important to the corporate life of the large organisation. The research workers found that the decisions made by the chief executive of the process firm studied tended to be those based on value judgments, many of which were in the field of labour relations.

The increased rationality in the decision making process in advanced technology facilitates not only delegation, but also the making of joint decisions. Management by committee seems to work better in the process production firm than in the mass production firm. The distinction between executives and advisory responsibilities tends to be less clear-cut. The two firms referred to earlier in this Paper, in which the organisational structure was of a functional kind, were both process firms. In neither case did this form of organisation result in inefficient administration. No conflict occurred between the orders issued, nor did confusion arise from lack of definition.

Another point of importance is that as technology advances, management performance becomes easier to measure. This, together with the fact that technical competence is important, makes selection for promotion a much less subjective process. The research workers found that in the process production firms they studied, there was much less strain and stress associated with promotion. The tendency for individuals to attach themselves to other individuals, to become an X's or a Y's man and to rise or fall with him, reaches its extreme point in mass production industry.

We have seen that as technology advances the physical limitations of production become increasingly controllable. Thus, in the very simple manufacturing processes where it is difficult to control physical limitations, relatively little pressure is put upon people. At the other end of the scale, the control exercised becomes so automatic and exact that pressure upon people is not very great. In process and automatic production, productivity is only associated indirectly with human effort ; people are hard-pressed only when things go wrong. In the middle ranges of the technical scale, however, considerable pressures are exercised over individuals in an effort to push back as far as possible the limitations of production. Targets are set ever higher, incentives are offered, and manufacture proceeds by drives of one kind or another.

A disciplinary framework

Moreover, in process industry the plant itself constitutes a framework of discipline and control. The demands on the operatives are imposed by the plant rather than by the supervision. Most people resent the authority that is exercised over them in this way less than they resent the authority that is imposed on them by others. Thus, as technology advances our entire concept of authority in industry may change. The research workers found that in process industry the relationship between superior and subordinate was much more like that between the booking clerk at a travel agency and his client, than that between the foreman and the operator in mass production. The process foreman's job was to organise labour within the limitations and conditions set by the plant itself. These limitations and conditions were as fully understood by the operators as

by the foremen themselves and there was no question of the superior imposing his will upon his subordinates.

An example of the difference in attitude in the two types of industry is that while the mass production foreman often has to work hard to prevent his operators from slipping off to wash their hands or to gather at the clock before finishing time, the process operator will often arrive early for his night shift in order to allow the man he is relieving to get away to have a quick drink before closing time. He is well aware that the plant cannot be left unattended and automatically makes the necessary arrangements.

There is evidence to suggest that with technological advance, the supervisor and subordinate will be drawn together again by a common understanding and appreciation of the demands of the job itself, as they were in the pre-industrial period or as they still are in unique article production.

It is interesting to speculate whether these new developments in technology will bring to senior positions in manufacturing firms a different kind of executive personality. There are indications that this may happen. The manager of tomorrow will be more analytical than intuitive. His administrative skill will be built up on a basis of technical competence. He will be a functional rather than a personality leader. His authority will be of a different kind; he may have more leisure, for he is likely to be hard-pressed only when things go wrong.

The research indicated quite specifically that although there are certain problems of monotony and boredom associated with the monitoring type of job in process industry, these are more than offset by the relaxation of tension in the atmosphere at all levels of the organisation. The automatic factory is likely to provide an environment for those employed in it far more conducive to human happiness than the mass production environment.

It has only been possible here to put forward a few of the ideas that have emerged from this research project. When the report is published it will contain detailed descriptions of the various situations studied showing the evidence on which these generalisations are made.

TABLE I

SOME EXAMPLES OF THE DIFFERENCES IN THE PROPORTION OF MANAGERIAL AND SUPERVISORY STAFF EMPLOYED IN FIRMS OF SIMILAR SIZE

Type of Production System	Number employed	Managerial and Supervisory staff	Non-supervisory staff	Proportion of Supervisory to Non- supervisory
Unique Article Production				
Factory A	455	21	434	1 in 21
B	948	25	923	1 in 38
C	4,550	175	4,325	1 in 26
Mass Production				
Factory A	452	30	422	1 in 15
B	975	60	915	1 in 16
C	3,519	160	3,359	1 in 22
Process combined with Mass Production				
Factory A	553	55	498	1 in 10
B	1,098	110	988	1 in 10
C	4,050	270	3,780	1 in 15
Process Production				
Factory A	498	55	443	1 in 9
B	888	110	778	1 in 8
C	3,010	375	2,635	1 in 8

TABLE II

THE NUMBER OF DISTINCT LEVELS OF AUTHORITY IN THE MANAGEMENT HIERARCHY IN THE MAIN PRODUCTION GROUPS

	Number of levels:— 2	3	4	5	6	7	8 or more	Median	Total
Number of unique article production firms	3	18	3	–	–	–	–	3	24
Number of mass production firms	–	2	16	7	3	2	1	4	31
Number of process production firms	–	–	2	6	7	5	5	6	25
Totals:	3	20	21	13	10	7	6	4	80

TABLE III

SPAN OF CONTROL OF CHIEF EXECUTIVE ANALYSED BY SYSTEM OF PRODUCTION

	Number controlled:— 2	3	4	5	6	7	8	9	10	11	12	13	14 & over	Median	Total
Unique article Production	–	2	3	3	5	2	3	1	1	–	2	2	–	6	24
Mass production	3	5	8	6	5	1	1	2	–	–	–	–	–	4	31
Process production	–	–	5	1	4	2	2	2	1	–	2	3	3	8	25
Total firms covered	3	7	16	10	14	5	6	5	2	–	4	5	3	6	80

TABLE IV

SPAN OF CONTROL OF FIRST LINE SUPERVISOR ANALYSED BY SYSTEM OF PRODUCTION

	Number of people controlled:— Less than 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	Unclassified	Median	Total
Unique article production firms	1	6	8	4	3	1	–	–	–	1	23	24
Mass production firms	–	1	2	5	9	4	5	1	3	1	49	31
Process production firms	6	12	5	2	–	–	–	–	–	–	13	25
Total firms covered	7	19	15	11	12	5	5	1	3	2	28	80

TABLE V

EMPLOYMENT OF GRADUATES ANALYSED BY SYSTEM OF PRODUCTION

	Total	Number employing graduates	%
Unique article production firms	24	9	37
Mass production firms	31	8	26
Process production firms	25	20	80
Process combined with mass production firms	9	7	78
Totals:	89	44	49

TABLE VI

GRADUATES EMPLOYED IN LINE AND STAFF DEPARTMENTS

	Both Line and Staff	Line only	Staff only	Neither	Total
Unique article production firms	1	–	8	15	24
Mass production firms	1	1	6	23	31
Process production firms	18	2	–	5	25
Process combined with mass production firms	5	–	2	2	9
Totals:	25	3	16	45	89

TABLE VII

PROPORTION OF QUALIFIED TO NON-QUALIFIED STAFF IN THE 44 FIRMS EMPLOYING GRADUATES

	More than 1 in 2	1 in 2	1 in 3	1 in 4	1 in 5	1 in 6 to 10	1 in 11 to 20	1 in 21 or more	Unclassified	Total
Unique article production firms	–	1	1	1	–	3	2	–	1	9
Mass production firms	–	–	–	–	–	1	2	3	2	8
Process production firms	2	3	1	2	2	6	3	1	–	20
Process combined with mass production firms	–	2	–	–	–	3	–	2	–	7
Totals:	2	6	2	3	2	13	7	6	3	44

TABLE VIII

LABOUR COSTS EXPRESSED AS A PERCENTAGE OF TOTAL COSTS

	Less than 12½%	12½–25%	26–50%	Over 50%	Total
Unique article production firms	1	4	14	4	23
Mass production firms	1	10	11	6	28
Process production firms	8	8	4	–	20
Process combined with mass production firms	3	5	1	–	9
Totals:	13	27	30	10	80

TABLE IX

AVERAGE LABOUR COSTS OF EACH PRODUCTION GROUP

Unique article production	36%
Mass production firms	34%
Process production firms	14%
Process combined with mass production firms	16%

TABLE X

RATIO OF MONTHLY AND WEEKLY PAID STAFF TO HOURLY PAID OPERATORS BY SYSTEM OF PRODUCTION

	1 to $\frac{1}{3}$	1 to $\frac{1}{2}$	1 to 1	1 to 2	1 to 3	1 to 4	1 to 5	1 to 6	1 to 7	1 to 8	1 to 9	1 to 10	1 to 11 or more	Unclassified	Total
Unique article production firms	1	1	1	2	2	1	4	1	3	2	2	1	1	2	24
Mass production firms	–	–	–	–	–	–	8	9	6	7	–	–	–	1	31
Process production firms	–	1	4	6	10	1	–	1	–	1	–	–	–	1	25
Process combined with mass production firms	–	–	–	–	1	3	–	2	–	–	2	1	–	–	9
Unclassified	–	–	–	–	–	–	–	–	–	–	–	–	–	11	11
Totals:	1	2	5	8	13	5	12	13	9	10	4	2	1	15	100

TABLE XI

RATIO OF INDIRECT TO DIRECT LABOUR ANALYSED BY SYSTEM OF PRODUCTION

	1 to $\frac{1}{3}$	1 to $\frac{1}{2}$	1 to 1	1 to 2	1 to 3	1 to 4	1 to 5	1 to 6	1 to 7	1 to 8	1 to 9	1 to 10	1 to 11 or more	Unclassified.	Total
Unique article production firms	–	–	1	1	3	3	4	3	1	2	2	2	–	2	24
Mass production firms	–	–	1	2	2	2	2	2	2	3	2	3	4	6	31
Process production firms	3	5	9	8	–	–	–	–	–	–	–	–	–	–	25
Process combined with mass production firms	–	–	1	3	2	2	–	–	–	–	–	–	–	1	9
Unclassified	–	–	–	–	–	–	–	–	–	–	–	–	–	11	11
Totals:	3	5	12	14	7	7	6	5	3	5	4	5	4	20	100

SCHEDULING FOR BATCH PRODUCTION

by Dr. S. EILON, A.M.I.Prod.E.

Dr. Eilon graduated from the Israel Institute of Technology, Haifa, in 1945, *was awarded a year later the degree of Dipl.-Ing., and served his apprenticeship with the Palestine Electric Company Ltd. With the outbreak of war in Israel in* 1948 *he was commissioned to the Israeli Defence Forces, where he acted in various capacities for two years. He then served for three years with the rank of Major as Commanding Officer of the Israeli equivalent of R.E.M.E. workshops, charged with both technical and administrative responsibilities.*

In 1952, *he came to Imperial College, London, for post-graduate studies. A year later he was awarded the D.I.C. and was appointed a Research Engineer, was later awarded the Ph.D. by the University of London, and in May,* 1955, *he became a lecturer in Production Engineering at the Imperial College.*

BATCH production is necessary when the demand for a commodity is limited or when the rate of production is so high, compared with the rate of consumption, that they cannot be geared to each other by utilising continuous production. The product is, therefore, manufactured periodically in a quantity which would be sufficient to satisfy the demand for some time, until production of the product is resumed. In the interval time between two production periods, the plant and equipment can be used for the manufacture of a variety of goods in a similar fashion. A complete production cycle can thus be organised, in which each product, in turn, is manufactured in quantities corresponding to the total demand for it throughout the cycle time.

Two basic problems immediately present themselves : first, if each product were to be analysed by itself, disregarding any effects other products might have on the schedule, what is the quantity (or lot-size) that should be aimed at each time the product is manufactured ? Secondly, once the " best " lot-sizes for each product have been determined, how can a satisfactory master production schedule be set to take account of the plant capacity and the effects of these lot-sizes on the cycle time ? We shall now study each of these problems in turn.

Definition of lot sizes

In continuous production, the average rates of production and consumption are virtually the same. A buffer stock is built to take care of possible stoppages or breakdowns. If the production rate remains constant, the stock level will vary according to fluctuations in demand. Alternatively, the stock may be kept more or less at a constant level, while production rate is regulated to follow trends or changes in demand, in order to avoid excessive increase of stocks.

In batch production the stock has inevitably to be raised to a predetermined value before the production of another article is undertaken by the plant. If the stock level is kept too low, that is, a small lot is produced, the set-up costs per piece and the set-up time would be high. From the production point of view long runs are desirable, but if too large a lot is produced and stocked, high carrying costs are incurred, in the form of interest charges on the capital invested and in storage, maintenance and deterioration costs while the goods are in the stores. The main factors affecting the selection of lot sizes may be summarised as follows :

1. Set-up costs of machines and other costs of preparation for the run.
2. Consumption rate.

3. Production rate.
4. Interest charges per piece per unit time.
5. Average storage costs (including maintenance of products in stores and deterioration).
6. Sales price.

The selection of a lot-size is evidently a question of determining an optimum value which will yield the best possible results, when the criterion for judging these results has been adequately defined. This problem has been known for the past forty years and numerous attempts at a solution are recorded in literature. Most of the suggested solutions were concerned with finding the lot-size which results in minimum total production costs per piece, but as this may not always be the only consideration, and in order to understand the consequences of selecting a lot-size, it is desirable to analyse the following four criteria : minimum costs per piece, maximum profit for the batch, maximum return (ratio of profit to investment) and maximum rate of return (taking account of the time in which this return is effected).

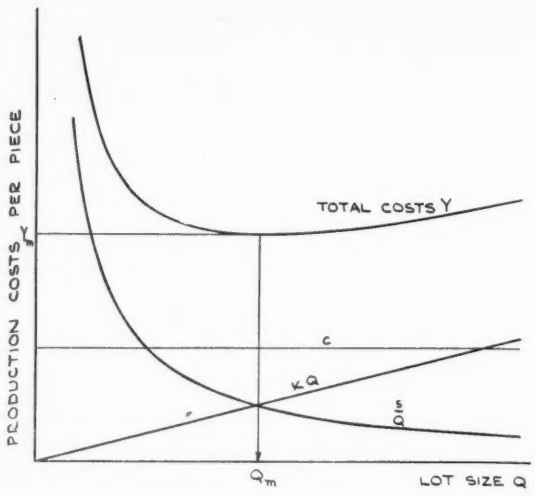


Fig. 1. Production costs per piece.

Minimum costs per piece

The total costs per piece, shown in Fig. 1, can be expressed by the function

$$Y = \underbrace{c}_{\text{constant costs}} + \underbrace{\frac{s}{Q} + KQ}_{\text{variable costs}}$$

where :

Y = total costs per piece.
Q = the lot-size.
c = constant costs per piece (comprising of labour, materials and overheads), which are virtually independent of the lot-size.
$\frac{S}{Q}$ = set-up and preparation costs per piece (s being the set-up costs for the lot) ; these costs are reduced with the increase of the lot-size.
KQ = the carrying costs per piece ; these increase linearly with the lot-size.

The minimum-cost-lot-size (Q_m) is the one that results in minimum total costs per piece (Y_m), and it can be shown that this lot size also provides for maximum return, i.e., maximum ratio of profit to investment. The value of Q_m can be determined by one of the following methods :

(a) Use of formula :—

This has been a popular method, expounded by many authors. Minimising the costs function, the lot size can be shown to be

$$Q_m = \sqrt{\frac{s}{K}}$$

and substantially, the difference between the various expressions which were published since the early twenties lies in the evaluation of the factor K and in the importance attributed to some variables likely to affect it. Many formulae were indeed very elaborate (for instance the thorough analysis undertaken by F. E. Raymond, [2] and [3]*), taking account of numerous factors beside the first five listed above (the sixth factor, the sales price, does not affect the point of minimum costs, but plays an important role when other criteria are considered). Some of these formulae pertain to be very accurate, but there is reason to doubt this presumption. For one thing, the underlying assumption is that the total costs function is a quadratic one, having linear terms for the carrying costs and hyperbolic terms for the preparation costs as the only variable features of the function. Such an assumption, as a prelude to a very strict mathematical treatment and a claim for high accuracy, is hardly justified. The described function of costs per piece is at best a convenient working model, which may within limitations represent the problem under review. Secondly, the complex formulae imply that the variables—and there are many—should be accurately determined, and it is doubtful whether this can always be done. From the practical point of view elaborate expressions are cumbersome to handle and evaluation of many variables may be both a difficult and a lengthy task.

The first solutions suggested in the early twenties are far simpler to use, notably the formula by Camp [1] [5], which is often quoted even nowadays. In this formula the carrying costs depend only on the interest charges per piece and on the consumption rate. Storage costs and rate of production are not accounted for and in cases where these are not negligible, results from Camp's formula are no longer satisfactory.

It is therefore desirable to include all the five main factors mentioned above to provide a reasonably accurate tool, which at the same time is not too elaborate to use, and such an expression, suggested by the author [8], is presented in the Appendix.

(b) Use of a nomograph :—

A nomograph facilitates rapid calculations, and with suitable scales, yields quite satisfactory results.

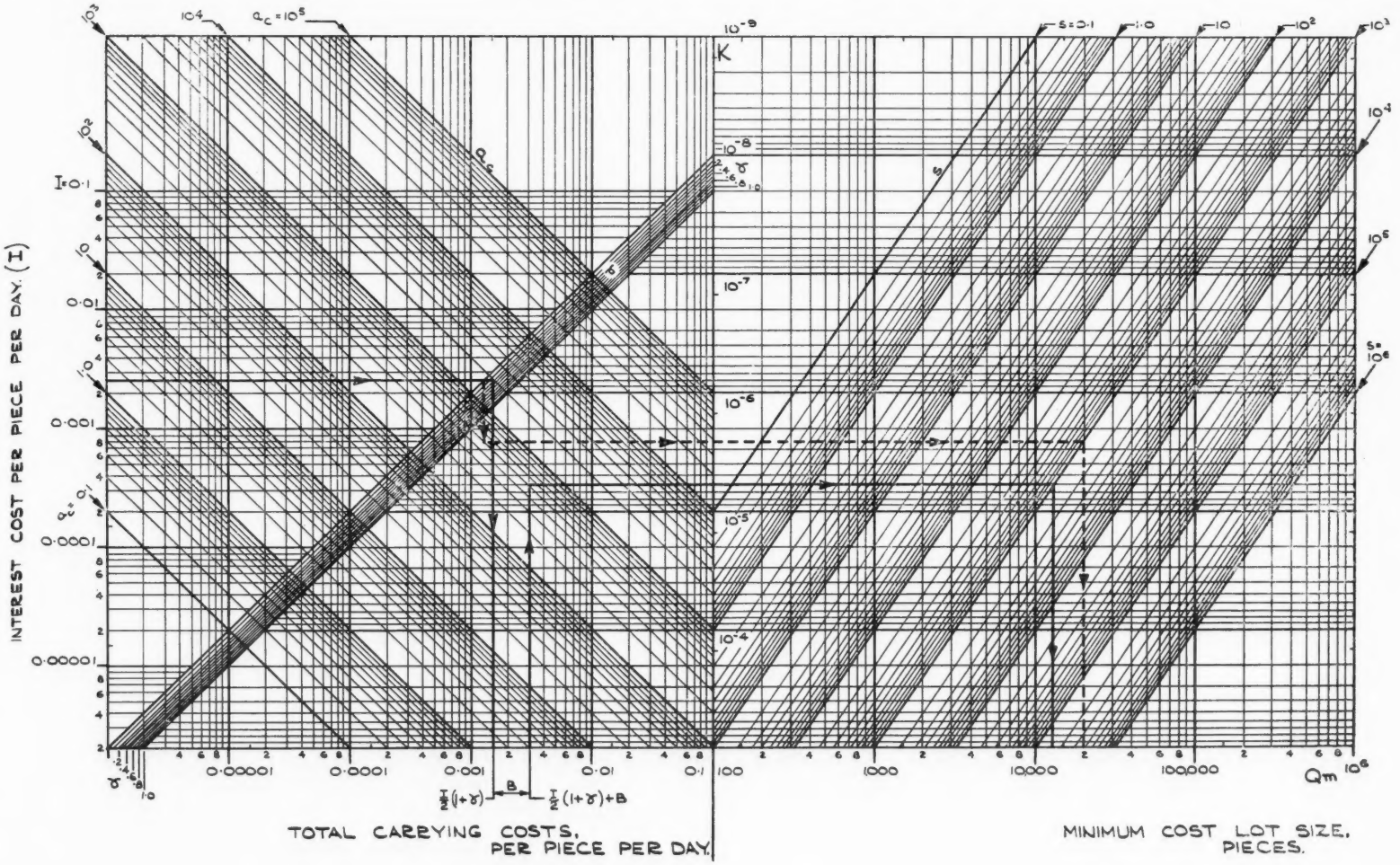


Fig. 2. Nomograph for computing the minimum-cost-lot-size.

The nomograph shown in Fig. 2 is based on the formula given in the Appendix, and the way to use it is illustrated by the following example :

Supposing we take the data of the case given in the Appendix :

Interest charges per piece $I = 2.5 \times 10^{-3}$ shillings per piece per day

Ratio of consumption rate to production rate $\gamma = 0.2$

Rate of consumption $a_c = 500$ pieces per day

Average storage costs $B = 1.5 \times 10^{-3}$ shillings per piece per day

Set-up and preparation costs $s = £50 = 1000$ shillings.

The interest charges are marked on the I ordinate on the left and a horizontal line drawn to intersect the γ lines at $\gamma = 0.2$. The abscissa now gives the interest charges, corrected to account for the effect of the production period $\left(\frac{I}{2}(1+\gamma)\right)$. The average storage costs are added on this scale ($1.5 \times 10^{-3} + 1.5 \times 10^{-3} = 3.0 \times 10^{-3}$) and a vertical line drawn to intersect the a_c lines at $a_c = 500$. The ordinate at this point gives the total carrying costs factor K (measured on the K scale ; in our example $K = 6.0 \times 10^{-6}$). Once the value of K has been established, we can proceed to find Q_m by the relation $Q_m = \sqrt{\frac{s}{K}}$, which is described by the right-hand half of the nomograph. From the ordinate K a horizontal line is drawn to intersect the s lines at $s = 1000$, giving an abscissa of $Q_m = 10300$ pieces.

When the ratio γ is very small, or when lot sizes have to be computed for inventory purposes, the procedure of intersecting the γ lines can be by-passed, either by using $\gamma = 0$, or by directly marking $\frac{I}{2}$ on the abscissa on the left.

The effect of using the simple Camp relation is also illustrated on the nomograph. No use is made of the parameter γ and the left-hand abscissa is not corrected for storage charges. In our example this would lead to $Q_m = 20000$ pieces. It is obvious from the nomograph that only when γ and B are negligible, will the error resulting from Camp's formula be small.

(c) A graphical method.

This method can also be called " learning from bitter experience." If a product has been manufactured several times in various quantities, the curve of costs per piece versus lot-size can be plotted (Fig. 3), and the point of minimum costs obtained from it.

The main disadvantages of this method are: first, a large number of points is required to facilitate the construction of the curve, all relating to circumstances in which the constant costs per piece are the same. If this part of the cost function undergoes a change, the curve is no longer valid. Secondly, because the curve is flat at the minimum point, it may be difficult to establish where this point is.

This may not be considered a practical method for current evaluation of Q_m, but it can provide a useful tool for management when trying to assess whether a product with a history behind it is sensitive to variable costs, in which case a fuller analysis is justified.

(d) A modified graphical method.

In this method it is not necessary to plot the curve or to have a large number of points on it. It is sufficient to locate two points on either side of Q_m which have the same ordinate, i.e., the same production costs per piece, corresponding to two lot-sizes Q_I and Q_{II} (Fig. 3). It can be shown (see Appendix, (7)), that the relation between these lots and Q_m is

$$Q_m = \frac{Q_I + Q_{II}}{2p}$$

where the factor p is the variable costs per piece incurred at Q_I and Q_{II} compared with those incurred when Q_m is produced. The fact that it is necessary to assess the value of p by the available data may introduce a slight error in the calculations, but the accuracy of Q_m mainly depends on the accuracy with which Q_I and Q_{II} can be determined.

(e) Equating the variable costs.

At the point of minimum costs, the two terms of variable costs are equal :

$$KQ_m = \frac{s}{Q_m}$$

This fact provides a good method for finding the point of minimum. Once the values of s and K have been determined, the curves of the two variables are plotted (Fig. 4) and Q_m is given by the abscissa of the point of intersection, which is more clearly definable than the determination of a minimum point on a shallow portion of a curve.

Production range

A production range may be likened to dimensional tolerances on engineering components. A certain lot-size may be considered the best target that should

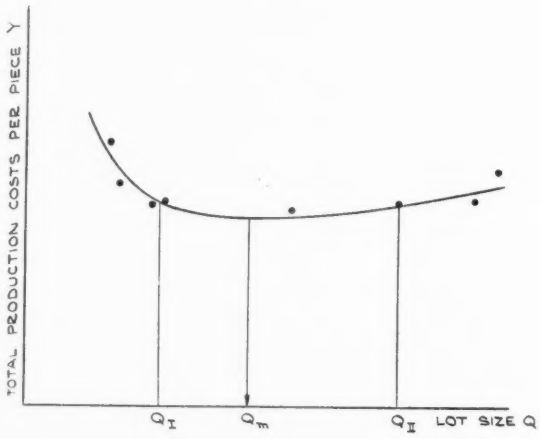


Fig. 3. Graphical method for finding the minimum-cost-lot-size.

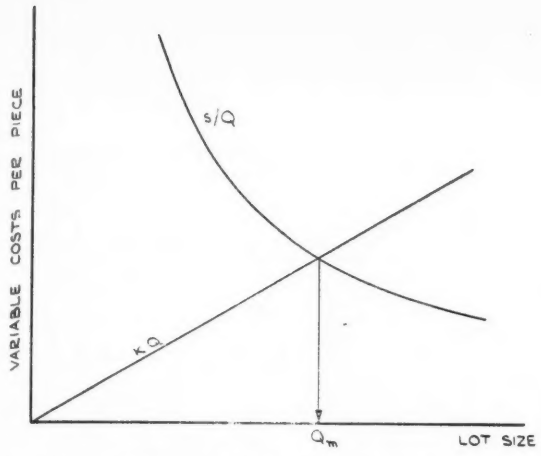


Fig. 4. Equating the variable costs. *Qm* is found at the point of intersection of the two variable curves.

be aimed at, but in practice it may be impossible to obtain a satisfactory production schedule if only the ideal lots are acceptable.

Due to the fact that the production costs function is flat in the region of its minimum point, any slight increase in production costs would result in two lot-sizes on either side of Q_m and they would also be acceptable (Fig. 5). These two become the limits of the production range, within which any selected quantity would not lead to an increase in costs above a predetermined value.

These limits can be shown to be dependent on the ratio of allowable variable costs to minimum variable costs per piece (denoted by the factor p), as described in the Appendix. If the variable costs are allowed

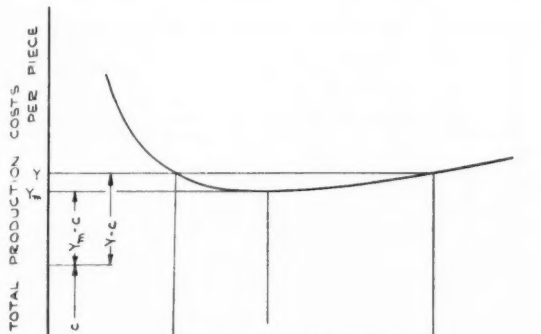


Fig. 5. Deviations from *Qm* and the production range.

to increase by 1% (or $p = 1.01$) the limits of the production range are 13.2% below to 15.2% above the minimum-cost-lot-size. If the increase is by 5% ($p = 1.05$) the range is —27% to + 37% and when $p = 1.10$ it becomes —36% to + 56%. Thus, comparatively great flexibility is obtained with only a moderate increase in costs. The resultant increase in variable costs when the lot-size is selected is given in the first two columns of Table 1.

If a limited increase in the production costs is not the only factor that matters, the production range can be modified according to any further criteria and dictates (for instance, when it is desirable to control the level of rate of return and ensure that it does not fall below a certain limit).

Maximum profit for the batch

Turning to another criterion, maximum profit is often considered to be an appropriate yardstick by which performance can be judged. A function of profit can be defined, in which the variables are the quantity produced, the costs per piece and the sales price. The maximum-profit-lot-size can be found when this function is maximised. There are two methods to find this lot size :

(*a*) *By formula.*

It can be shown that the lot-size is dependent on the sales price and on Q_m (see Appendix). It is evident from the formula that in order to obtain maximum absolute profit, it is necessary to produce a larger lot-size than Q_m (when the sales price is higher than the production costs).

(*b*) *By a graphical method.*

The minimum-cost-lot-size and the minimum costs per piece are first computed and these co-ordinates describe the point A (Q_m; Y_m) in Fig. 6. The constant cost per piece c is marked on the ordinate (point B) and the sales price indicated by a horizontal line. A and B are joined and the maximum profit lot size (Q_p) is given by the point of intersection of this line with the price line.

There are several implications involved in the production of a lot-size larger than Q_m and these have to be considered :

1. Higher costs per piece are incurred. This may be undesirable if there is a likelihood of a change in pricing policy. The increase may not be serious, as the curve for total costs is usually quite shallow beyond the point Q_m (see Fig. 1).
2. Higher investment is necessary.
3. The product will remain a longer time in stock, leading to slower turnover of the capital.

Maximum rate of return

The rate of return is defined as the ratio of profit to investment per unit time. Maximum rate of return ensures that production yields the best possible results in terms of annual profits for each pound invested, and the batch giving this maximum may be called the " economic-lot-size " (denoted by Q_e). To achieve a quick turnover of the capital, a short cycle time is required, leading to the conclusion that a lot-size smaller than Q_m should be produced for this

Table 1

EFFECT OF SELECTING A LOT SIZE

($p' = 1.40$; $u = 5.0$)

$q = \frac{Q}{Q_m}$	$\frac{\text{Variable costs}}{\text{Min. var. costs}}$ p	Costs per piece I	Investment	Profit	$\frac{\text{Profit}}{\text{Investment}}$	Rate of return
0.50	1.250	107.1	53.6	18.8	35.1	70.2
0.60	1.133	103.8	62.2	40.0	64.2	107.0
0.70	1.064	101.8	71.3	58.8	82.3	117.6
0.73	1.050	101.4	74.1	63.9	86.2	118.1
0.80	1.025	100.7	80.6	75.0	93.1	116.4
0.90	1.005	100.1	90.1	88.8	98.6	109.6
1.00	1.000	100.0	100.0	100.0	100.0	100.0
1.10	1.005	100.1	110.1	108.6	98.6	89.6
1.20	1.017	100.5	120.6	114.9	95.3	79.4
1.30	1.034	101.0	131.3	119.0	90.6	69.7
1.37	1.050	101.4	138.9	119.9	86.3	63.0
1.40	1.057	101.6	142.2	120.1	84.5	60.4
1.50	1.083	102.3	153.5	118.9	77.4	51.6
1.60	1.113	103.2	165.1	114.8	69.6	43.5
1.70	1.144	104.1	177.0	108.8	61.5	36.2
1.80	1.178	105.1	189.2	99.9	52.8	29.3
1.90	1.213	106.1	201.6	88.8	44.1	23.2
2.00	1.250	107.1	214.2	75.0	35.0	17.5

purpose. The methods to compute the economic-lot-size are :

(*a*) *By formula.*

The first attempts at a solution were made by F. E. Raymond (1929), [2] and [3], and later by P. T. Norton, (1933) [4]. Their method, in effect, comprised of the basic formula for Q_m, but the interest charges were defined to include both the interest paid on the capital and the interest expected as a return on it. Thus, supposing 6% is the rate of interest paid and 15% is the desirable rate of profit, then 6% is taken as a basis for determining the interest charges per piece I for the computation of Q_m and 21% is the basis for the economic lot-size.

In this method the rate of return is arbitrarily chosen, with no connection to the sales price (indeed,

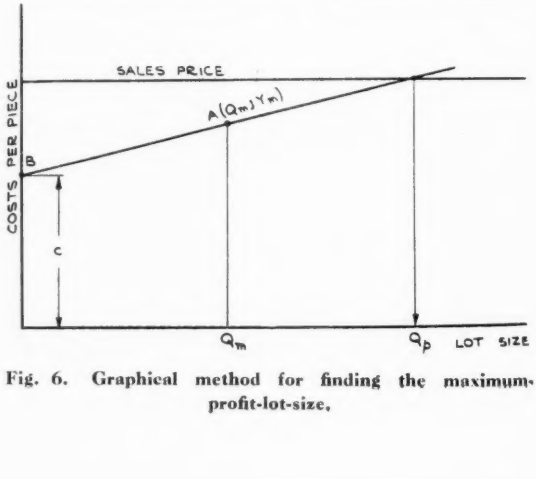


Fig. 6. Graphical method for finding the maximum-profit-lot-size.

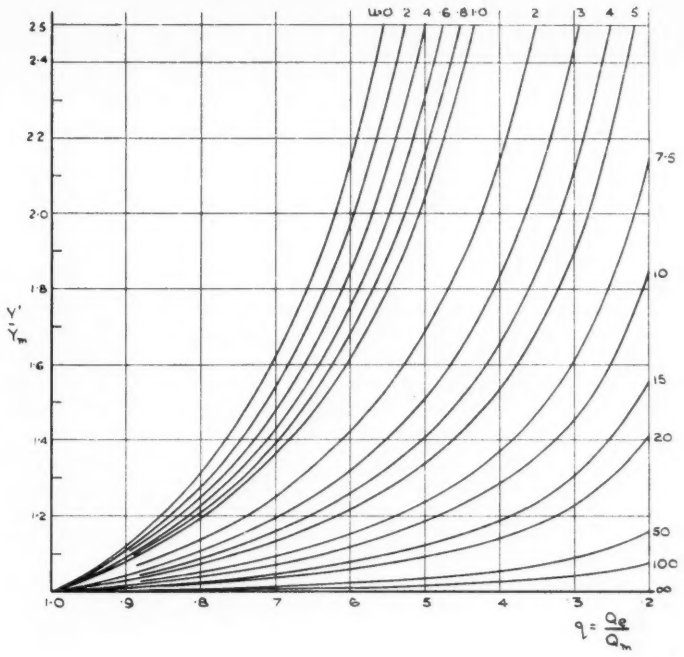


Fig. 7. Non-dimensional curves for computing the economic-lot-size. $\frac{Y'}{Ym}$ is the ratio of sales price to minimum production costs per piece.

the sales price does not appear in the suggested formulae). Also, it is only related to the constant costs per piece, but not to the variable terms in the costs function.

Another method [8] develops an expression for the rate of return in terms of the sales price, the production costs and the quantity produced, and the economic-lot-size is obtained when this function is maximised. The result is an equation of the fourth order (given in the Appendix), which can be simplified by an approximation. The complete equation is not easy to handle when quick results are sought in practice, but the approximation is simple enough and would yield satisfactory results, provided the lot-size is not too small compared with Q_m.

(b) Use of curves.

The economic-lot-size can be readily computed from a series of curves [8], which are based on the full expression and are shown in Fig. 7. The ratio q of the economic-lot-size to Q_m is easily found when the ratio of sales price to minimum production costs Y'/Y_m and the parameter u are known (u is the ratio of constant costs per piece to half the variable costs when Q_m is produced). In the example discussed in the Appendix it can be shown that $u = 94$. Supposing the sales price is 10.4 shillings per unit, thus resulting in $\frac{Y'}{Y_m} = 1.08$.

From Fig. 7 : $q = 0.2$

Hence the economic lot-size is $Q_e = qQ_m = 2060$ pieces.

It is interesting to note that the minimum-cost-lot-size remains the basis for calculating both the maximum-profit lot and the economic-lot and it must be computed before the effect of the sales price on these criteria can be accounted for.

The adoption of the economic-lot-size, leading to the production of a lot smaller than Q_m has some interesting features :

1. Higher costs per piece than Y_m are incurred, as in the case of the maximum profit lot, only now we are below Q_m where the costs curve (Fig. 1) is steeper and the costs function is more sensitive to the quantity produced.
2. Less investment is required, hence less capital is tied to a particular production run.
3. Production time is shorter, hence production techniques may not get a chance to become fully developed as in long smooth runs, when production rates could be greatly improved. Also, short runs increase the relative length of setting-up time and non-productive-time of the equipment.

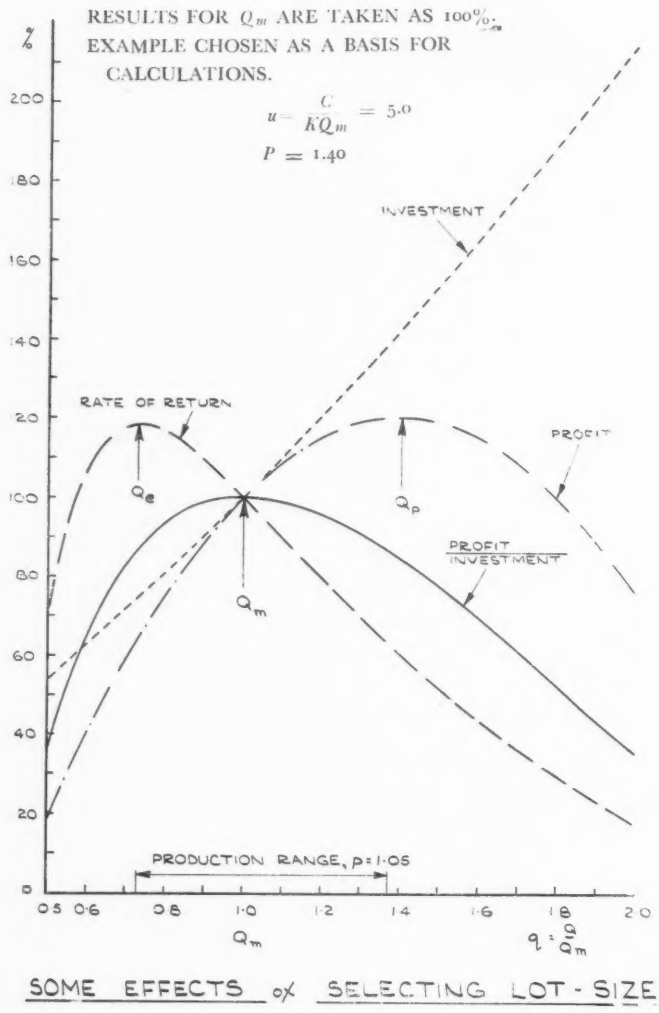
Analysis of the various criteria

The implications resulting from the selection of lot sizes were discussed above and it may be useful to illustrate some of these effects by an example : Suppose the parameter $u = 5.0$ (which means that the variable costs constitute at least 28.6% of the total production costs) and $p' = 1.40$ (the sales price in this case being 11.4% above Y_m.) The effect of lot-size on the variable costs factor p, production costs per piece, investment, profit, profit/investment and rate of return is given in Table 1 and some of these functions are shown in Fig. 8, the results for Q_m being taken as 100%.

An increase in variable costs of 25% causes in our case an increase of 7.1% in total production costs. The investment obviously increases with the lot-size, but owing to the increase in costs per piece, the investment is more than doubled when the minimum-cost-lot-size is doubled ($q = 2.0$). The profit function is maximum at $q = 1.4$ and is 20% higher than the profit at Q_m, but investment tied to the production run is 42% higher, ratio of profit to investment is down 15% and rate of return is 40% lower and only about a half of its maximum. Maximum rate of return is obtained at $q = 0.73$, and these two lot-sizes are approximately the limits of the production range for $p = 1.05$. Ratio of profit to investment for the economic lot-size is about the same as for the other end of the range, but the required investment is almost halved.

The advantages of the economic lot-size are self-evident from Fig. 8, and unless special benefits are to be gained from a larger lot (such as better production methods, or envisaged changes in labour and material costs), it is preferable to the other criteria for the choice of lot sizes. The function of rate of return is, however, very sensitive to the lot-size and this fact leaves little room for flexibility in the form of production ranges for scheduling purposes. Moreover, below the point of the economic lot both the return and rate of return deteriorate very quickly. A change in pricing policy may adversely effect both the return and rate of return.

It would appear from the above that in most cases the best production range should probably lie between Q_e and Q_m, provided the production costs at Q_e are not too high. This range, however, may prove to be too narrow and may have to be relaxed when scheduling difficulties arise.



SOME EFFECTS OF SELECTING LOT-SIZES

Fig. 8. Some effects of selecting lot-sizes.

Multiproduct scheduling

It is one thing to define what the lot-size for each product should be, and another to fit it in a production schedule. If a production cycle is planned, it is usually intended that the quantities for each product should cover the demand for the cycle time. But the computed lot-sizes may be too large or too small to satisfy this requirement. Indeed, with different set-up costs, carrying costs and consumption rates, it would be a coincidence if the lot-sizes of the various products would all have the same consumption period.

It is thus clear that deviations from the ideal lot-sizes are inevitable, if we are to guarantee that the products should always be available. The ratio between the various quantities produced during the cycles is governed by the ratio between the respective consumption rates and it is, therefore, necessary to determine a production plan that would give the best possible results under the circumstances. Profit or return can be maximised for the whole cycle, rather than for any particular product, and the appropriate lot-sizes for each product can be computed, as shown in the Appendix.

We have now two régimes : one yielding a solution when each product is considered individually, the other giving a solution when the cycle is considered as a whole, and most probably these solutions are at variance with each other. The first solution is unacceptable because the lot-sizes are not compatible with the production cycle, whereas if the second solution were to be adopted, too high production costs for some of the products might be incurred and indeed some of them might be run at a loss.

It is, therefore, necessary to introduce some adjustments into the cycle plan and for that purpose one has to specify the allowable deviations from the minimum costs and from the point of maximum performance and hence set the production ranges. The production cycle should now consist of lots which fall within these ranges, and this is where flexibility for setting the production plan is introduced. Should the lots lie outside the ranges, they could be subdivided into smaller lots, each complying with the production ranges, or produced in an acceptable quantity once every two or more cycles. Thus, certain products would be produced more than once during the cycle, others may be missing from some cycles altogether.

Multi-scheduling six products — an example

The application of the multi-scheduling principle may best be illustrated by an example. Data of six products which have to be manufactured in a plant is given in Table 2.

The products have been arranged in the order of increasing consumption rate, and they vary considerably in their production rates, set-up costs and constant costs per piece. It is assumed that the products are not being manufactured simultaneously and that during the set-up period no production takes place. Usually among six products it may be found that at at least one has such a low variable-costs content that it can be produced within a very wide range with little effect on the total costs per piece, and this " slackness " greatly simplifies the problem of scheduling. In this example, however, strict limitations are imposed (shown in the last row in Table 2) for the allowable increase in variable costs above those which are incurred when the minimum-cost-lot-size is produced. As shown in Table 1 the increase in variable costs by 5% for products 1, 2, 3, 5, 6, is likely to cause an increase in total costs of the order of 1 or 2%. Because of the high constant costs content and comparatively low set-up costs of product 4, it is felt

Table 2

DATA OF SIX PRODUCTS TO BE MANUFACTURED

Product No.		1	2	3	4	5	6
Consumption rate (units/day)	a_c	20	24	30	36	40	50
Production rate (units/day)	a_p	100	150	200	110	400	280
Constant costs/piece (shillings)	c	4.0	1.6	6.0	12.0	16.0	6.0
Storage costs/piece per day (shillings)	B	0.001	0.001	0.0015	0.00125	0.002	0.00225
Set-up costs (shillings)	s	3000	1800	3600	1500	6000	30000
Set-up time (days)	t_s	4.0	2.4	4.8	2.0	4.0	8.0
Allowable increase in variable costs		5%	5%	5%	10%	5%	5%

Table 3

MINIMUM-COST-LOT-SIZES AND PRODUCTION RANGES FOR THE SIX PRODUCTS

Product No.			1	2	3	4	5	6
		Computed by						
Interest charges per piece per day	I	ic	1.6×10^{-3}	0.64×10^{-3}	2.4×10^{-3}	4.8×10^{-3}	6.4×10^{-3}	2.4×10^{-3}
Ratios : consumption	α	a_c/a_{c1}	1.0	1.2	1.5	1.8	2.0	2.5
production	β	a_p/a_{p1}	1.0	1.5	2.0	1.1	4.0	2.8
" γ "	γ	a_c/a_p	0.2	0.16	0.15	0.326	0.1	0.179
set-up		s/s_1	1.0	0.6	1.2	0.5	2.0	10.0
Carrying costs factor	K	$\frac{I(1+\gamma)+2B}{2a_c}$	0.98×10^{-4}	0.571×10^{-4}	0.96×10^{-4}	1.23×10^{-4}	1.38×10^{-4}	0.733×10^{-4}
Carrying costs factor ratio		$\frac{K\alpha^2}{K_1}$	1.0	0.839	2.205	4.07	5.63	4.67
Min. cost lot-size	Q_m	$\sqrt{s/K}$ Appendix, (2)	5540	5610	6120	3490	6590	20230
Variable costs factors	p		1.05	1.05	1.05	1.10	1.05	1.05
Production range		Appendix, (7)	4040—7600	4090—7690	4470—8390	2230—5450	4810—9030	14800—27700

that 10% increase in variable costs may be allowed for this product. The actual increase in total costs for each product is computed at the end of this analysis, after the final production schedule has been outlined.

The carrying costs, the minimum-cost-lot-sizes for each product and the allowable ranges of production have been computed and the results are shown in Table 3. The interest rate is taken as 12%, i.e., $i = \frac{12}{100} \times \frac{1}{300} = 4 \times 10^{-4}$ per day (assuming 300 working days in a year). Supposing it was thought advisable in this case to obtain minimum production costs per piece, because of possible pending changes in selling prices, thus under the circumstances maximum return should be aimed at. The production ranges could be modified to exclude values which lie above the respective minimum-cost-lot-size (to ensure a high rate of return), but as the allowable increase in costs is very limited in this example, the ranges are left unchanged to allow flexibility in scheduling.

The problem may be defined as follows : An analysis is required which would show whether it is possible to set such a schedule that each product is manufactured within the prescribed range and that each product will always be available. Alternatively, should that not be feasible, it is required to suggest a schedule which would give satisfactory results, under the circumstances. A safety allowance has to be taken into account to cover possibilities of delays, maintenance, breakdowns and other stoppages. The appropriate figure for such an allowance is determined by previous history of the machinery involved and other circumstances, and in our example it was assumed to be 5% of the total production time. The first attempt at a solution is illustrated in Table 4. The lot-size for product 1 is computed by expression (12) in the Appendix for maximum return as follows : From Table 3 $\Sigma s/s_1 = 15.3$

$$\Sigma K\alpha^2/K_1 = 18.41$$

Hence $g_1 = \sqrt{\frac{s/s_1}{K\alpha^2/K_1}} = \sqrt{\frac{15.3}{18.41}} = 0.911$

$\therefore Q_1 = g_1 Q_{1m} = 0.911 \times 5540 = 5050$ pieces

and $Q_2 = \alpha_2 Q_1 = 1.2 \times 5050 = 6060$ pieces, etc.

The lot-sizes quoted in the Table 4 ensure that throughout the consumption period $T_c = 252$ days, all products are available and that the suggested solution provides for maximum return not for each of the products individually, but for the programme as a whole. It is now necessary to apply two tests to ensure that the solution is compatible with the given data and can be carried out.

Table 4

FIRST SOLUTION FOR A PRODUCTION PLAN

Product			1	2	3	4	5	6	Remarks
Lot size	Q	Computed by	5050	6060	7570	9090	10100	12630	Consumption period $T_c = \frac{Q}{a_c}$ = 252 days
"p test"			√	√	√	x	x	x	
Production time (days)	T_p	Q/a_p	50.5	40.4	37.8	82.6	25.2	45.0	*Totals* $\Sigma T_p = 281.5$
Set-up time (days)	t_s		4.0	2.4	4.8	2.0	4.0	8.0	$\Sigma t_s = 25.2$
Total production time (days)		$T_p + t_s$	54.5	42.8	42.6	84.6	29.2	53.0	306.7
Production cycle	T_o	add 5%	Length of production cycle = 306.7 × 1.05 = 322 days.						

(1) *The "p test."* Each quantity is compared with the production range set in Table 3. The results for the first three products comply with this limitation, while the quantities for the last three fall outside the prescribed respective ranges. In the case of products 4 and 5 the quantities are considerably above those at minimum cost. This can be rectified by splitting the batches into lots, the size of which will fall within the production range. Hence, products 4 and 5 could be produced in two lots each of 4045 pieces and 5050 pieces respectively, the lots being more or less evenly distributed in the production cycle. Overshooting the higher limit of the production range does not present a serious difficulty; the reason for this lies mainly in the fact that the allowable relaxation factor on the available costs $p = 1.05$ is usually large enough to provide the necessary flexibility. The limits of the range in this case are 73%—137% of the minimum-cost-lot-size. If the figure emerging from the solution is, say, 150%, the batch can be divided into two lots, each being 75% in magnitude and so satisfy the requirements. Even when the batch size falls between the limits 137%—141%, the resultant increase in p above the 1.05 mark is so slight, that in most cases it can probably be tolerated (at 141% and 71% the value of p is 1.06). The division of the batch into lots having a smaller size than the minimum-cost one is even beneficial from the point of view of rate of return, as shown in Table 1, but it must be remembered that the production-cycle is thereby lengthened, due to the additional set-up time for the new lots. Another problem is to schedule these lots in the production cycle, placing them in such a way as to ensure that the products are available in the interval period between them, and that not too high a stock is carried from the first lot when the time for producing the second lot arrives.

More complicated is the case when the solution indicates that the quantity to be produced is below the allowable range, such as with product 6. If the quantity shown in Table 4 is adopted, the increase in variable costs would be 11%. The only possible course to follow—short of dropping product 6 altogether from our schedule—is to produce a quantity which would satisfy the demand during the period of two cycles. Thus, the production plan will have to provide for two modified cycles, different in length, one including product 6 and one without it.

(2) *The "cycle test."*—The length of the production cycle is worked out as shown in Table 4 and a comparison is made with the consumption period. This test is a more crucial test than the "p test," as it immediately shows what relation the load of the schedule has to the capacity of the plant. In the solution shown in Table 4 the plan provides for a consumption period of 252 days, but the length of the production cycle is 322 days. Hence, it is quite obvious that the proposed solution is incompatible with the data on the products and the capacity of the plant as given in Table 2. The plan to produce the six products is, in fact, too ambitious under the circumstances. Had the production cycle been found to be shorter than the consumption period, extra plant capacity would have been available and additional production could have been undertaken.

Methods leading to modified solutions

The double check as described above provides an answer to the question whether a satisfactory schedule is possible. Having shown that the solution in Table 4 is unacceptable, a modified solution may be sought on one of the following lines:

1. Increase the quantities, so that a longer consumption period is covered, the increase being

such that the new consumption period will be equal to the production cycle.

2. Re-examine the production range of the products and determine whether they can be relaxed.
3. Increase the capacity of the plant by adding or substituting some of the equipment, or by using overtime.
4. Attempt a more modest production plan by modifying the requirements that (*a*) all products must be produced, and/or (*b*) that all products must always be in stock.

The question which alternatives should be taken can be decided when the circumstances of the case have been fully analysed, but it may be useful to add a few comments on each method and outline the procedure which will lead to a final solution.

1. Increase the consumption period

The object of increasing the consumption period is to arrive at a situation which will satisfy the " cycle test." As such an attempt involves an increase in quantities, it is reasonable to assume that the " p test" could also be met.

To increase the consumption period T_c from 252 days in Table 4 to the level of the production cycle of 322 days, it is necessary to increase the quantities by 28%. To achieve this increase the production time for each product will have to be lengthened by 28%, and as the set-up time is likely to increase due to splitting of batches into lots, the total production time will probably rise by 28% or more. The new plan is, therefore, no better than the original one of Table 4, because the gap between the consumption period and the production cycle has not been bridged or even diminished. Hence, this method of trying to obtain a satisfactory plan by increasing the cycle time, does not lead to a solution and must be abandoned.

That this method is impracticable, can be demonstrated by the following considerations. We know that

$$\Sigma T_p + \Sigma t_s > T_c$$

This expression may be replaced by

$$\Sigma T_p + \Sigma t_s = T_c + G$$

where G is the gap between the production cycle and the consumption period.

Supposing we wanted to increase T_c by a factor e in such a manner that the " cycle test " is satisfied, thus leading to the production time being increased by the same amount. Then

$$e\ \Sigma\ T_p + \Sigma t_s = e\ T_c$$

$$\therefore e = \frac{\Sigma t_s}{T_c - \Sigma T_p}$$

$$\text{or } e = \frac{\Sigma t_s}{\Sigma t_s - G}$$

If the denominator is negative, the factor e has no meaning and the objective cannot be attained. This is in fact the case in our example in Table 4. If the denominator is positive, its magnitude compared to the numerator may be such as to cause the factor e to be very large, leading to a very long cycle. This may introduce additional serious complications, such as the determination of the position of the large number of sub-divided lots in the production cycle. In such cases the problem may be far more easily resolved by alternative 3, namely by increasing the rate of production.

2. Relaxation of the productive ranges

The advantage to be derived from this method is obvious ; the wider the production range, the bigger is the chance for the calculated lot-size to comply with the " p test." This may both eliminate the necessity to split a large quantity into lots on the one hand and the introduction of a two cycle system—owing to one quantity being too small—on the other. Scheduling is greatly simplified, and if the production ranges are wide enough to allow the first interim solution to be accepted, the procedure is indeed a straightforward one. Supposing in the example analysed above a variable costs factor $p = 1.10$ was allowed for products 4 and 5 and supposing $p = 1.11$ was tolerated for product 6, the first solution presented in Table 4 would then be acceptable, and only the quantity for product 4 would have to be split into two lots. Products 5 and 6 would be produced in the stated quantities every cycle and only once per cycle.

These advantages warrant a careful examination of the allowable increase in the variable costs. In many cases it may be found that a relaxation of this condition would not cause a serious increase in the total costs per piece, and therefore may be justified. The effect of the relaxation mentioned above on products 5 and 6 is as follows (costs expressed in shillings) :

	Product 5	*Product* 6
Min. variable costs	1.82	2.97
Min. total costs	17.82	8.97
Total costs for $p = 1.05$	17.91 (0.5% increase)	9.12 (1.7% increase)
Total costs for $p = 1.10$	18.00 (1.0% increase)	9.27 (3.3% increase)
Total costs for $p = 1.11$	—	9.30 (3.7% increase)

It is evident, therefore, that an allowable increase in p has little effect on the costs of product 5 and it may be concluded that its lot-size need not be subdivided. Whether the increase in total costs of product 6 can be allowed is a question that can only be decided when the full facts of the case under consideration are known.

It should be pointed out, however, that relaxation of the p limitation constitutes only a half measure in reducing the difficulties arising from the solution given in Table 4. The "p test" has nothing to do with the production capacity of the plant and the "cycle test" has yet to be met. Hence, a critical examination of the production ranges should be carried out in conjunction with a method which tackles the problem of cycle compatibility, either by increasing plant capacity or by reducing the production loading, two methods which will now be examined in some detail.

3. Increase the capacity of the plant

If the complete production programme as prescribed is to be maintained, i.e., all products must be manufactured and all must always be available, an increase of the output capacity of the plant is unavoidable. Having failed to increase the consumption period to the level of the production cycle, this method aims at reducing the production cycle to the level of the consumption period. This increased capacity of the plant may be achieved either by adding or improving existing machines, or by employing overtime or additional shifts. The exact method by means of which this increased capacity can be attained is a matter for management decision after the merits of the case have been properly scrutinized. Provided the "p test" is satisfied, the first step in our example would be to reduce the production cycle to 252 days.

The new production rate can then be computed in the manner shown at the bottom of the page :

Assuming the increased rate of production will be kept throughout, the production rate for each product should be increased by the factor $\frac{281.5}{214.8} = 1.31$, i.e., by 31%, and the production time for each product will be reduced by the same factor.

The new values of production rates will cause the ratios γ in Table 3 to decrease, thus leading to a slight increase in the lot sizes. But this effect is not likely to be marked. For product No. 1, for example, the new value of γ_1 is $\frac{0.2}{1.31} = 0.153$, resulting in $K_1 = 0.963 \times 10^{-4}$, $Q_{1^m} = 5570$ and the production range being 4070—7650. Unless the change in the ratios γ is considerable, there is no need to recalculate these quantities and the solution presented in Table 4 may be left as it is.

It is possible, of course, to adopt a policy whereby the rate of production is increased only during specific intervals in the cycle, by using overtime or shift work. For instance, one could visualise a solution by doubling the production rates of products 3 and 4, thus bringing down the production cycle to the desired level. However, when only some of the products are to be manufactured at an increased rate, the effect on γ can be large and the lot size may have to be re-checked. Whether a uniform increased rate of production or a concentrated effort in an intermittent fashion should be adopted is again a question of policy which management has to decide on.

This method of increased production rates—though sometimes a nuisance and not even always feasible for various reasons—is a useful and a comparatively simple tool from the point of view of scheduling, when a solution is sought for an ambitious production plan, such as the one shown in Table 4.

Problems presented by a product for which the computed lot-size is too small can also be tackled by increased production. The quantity quoted for product 6 in Table 4 does not pass the "p test," but as already mentioned it could be produced in a larger quantity (nearer to the minimum-cost-lot-size) once every two cycles, so that the consumption period of the product will be equal to the sum of the two production cycles. The production plan can be constructed by the following steps :

(*a*) Find the length of the consumption period of the short cycle (excluding product 6).

(*b*) Add the two consumption periods and compute the quantity for product 6 to satisfy the demand throughout the whole period.

(*c*) Apply the "p test" to determine the number of lots per batch.

(*d*) Adjust the production rates in the two cycles to bring the production cycles in line with the consumption periods, and modify the production plan accordingly.

(*e*) Check whether this adjustment will have any serious effect on the lot-sizes, and if so recalculate the quantities and repeat steps (*a*),

		Time quoted in Table 4 (days)	New time (days)
Consumption period	=	252	252
Production cycle	=	322	252
Set-up time	=	25.2	25.2
Set-up time and allowance	=	$25.2 \times 1.05 = 26.5$	$25.2 \times 1.05 = 26.5$
Hence, total production time + allowance	=	$322 - 26.5 = 295.5$	$252 - 26.5 = 225.5$
Total production time	=	281.5	$\frac{225.5}{1.05} = 214.8$

(*b*) and (*c*). Even if the quantities are greatly affected, it will be found that one repeat calculation will be sufficient.

(*f*) Apply the "p test" and the "cycle test" as a final check.

(*g*) Determine the final production schedule.

In the procedure outlined above, a decision has to be taken before step (*d*) on the question of intermittent or uniform increase rates of production. Let us now follow this procedure in an attempt to suggest a reasonable solution to our problem.

(*a*) In order to find the length of the shorter cycle, only the lot-size of product 1 needs to be computed, but it may be just as well to give the complete tentative solution, similar to Table 4, as it provides additional information which will be needed later. As in this cycle product 6 is not included, the data regarding this product in Table 3 may be ignored.

Hence $\Sigma s/s_1 = 5.3$

$$\Sigma K\alpha^2/K_1 = 13.74$$

$$g_1 = \sqrt{\frac{\Sigma s/s_1}{\Sigma K\alpha^2/K_1}} = \sqrt{\frac{5.3}{13.74}} = 0.621$$

leading to a lot-size for product 1

$$Q_1 = g_1 Q_{1m} = 0.621 \times 5540 = 3440 \text{ pieces.}$$

It is evident at this point that the value of g_1 is too low and that some of the quantities in the solution will be smaller than the lower limits of the respective production ranges and will not satisfy the "p test." Instead of proceeding with the complete tentative solution for the short cycle, a short-cut can be taken by stating that the lot-size of product 1 has to be increased, at least to the lower limit of the production range by selecting $g_1 = 0.73$. This is the lowest value for g_1 we dare take, as a lower value would violate the "p test." It is evident that by increasing g_1 the return of profit per investment is lower than the one that can be attained by $g_1 = 0.621$ as found above. If, however, the conditions as stated do not allow any increase in the price of the product above a certain level, and if the product must always be available, it must be understood that a solution for maximum return of profit cannot be achieved. It should also be stated that in general the point of maximum return of profit is attained when the first tentative solution passes the "p test" and the "cycle test." But when these conditions are not satisfied by the first solution—and it may be reasonably expected that in most cases they are not—any modifications introduced into this solution, such as division of batches into lots, or boosting one lot size to the production range level, may cause the solution to depart from the point of maximum return. The amount of such a departure and the question whether it is acceptable, is a subject of an additional check that can be carried out when the final solution has been suggested.

Assuming that in our case the condition limiting the increase in costs per piece is prevalent, and selecting $g_1 = 0.73$, then

$$Q_1 = g_1 Q_{1m} = 0.73 \times 5540 = 4040 \text{ pieces}$$

$$Q_2 = \alpha_2 Q_1 = 1.2 \times 4040 = 4850 \text{ pieces, etc.}$$

The interim solution of the short cycle is given in Table 5, in which it is concluded that the consumption period is 202 days. As in the case of Table 4, it appears that the production plan for the short cycle is too ambitious and overtime will have to be used, as shown later.

(*b*) The total length of the two cycles can now be found by adding the consumption periods: 252 + 202 = 454 days. The quantity for product 6 which should be produced in the long cycle is 454 × 50 = 22700 pieces. The modified version of Table 4 is shown in Table 6.

(*c*) The application of the "p test" to Tables 5, 6 shows that none of the quantities in the two interim solutions is below the appropriate production range. Product 5 will have to be produced in two lots in the long cycle, while the quantities for product 4 can be divided into either two or three lots in both cycles.

Table 5

INTERIM SHORT CYCLE PLAN

Product		1	2	3	4	5	Remarks
Lot size	Q	4040	4850	6060	7280	8090	Consumption period $T_c = \frac{Q}{a_c} = 202$ days
"p test"		√	√	√	x	√	
No. of lots		1	1	1	2	1	
Production time (days)	T_p	40.4	32.3	30.3	66.2	20.2	Totals $\Sigma T_p = 189.4$
Set-up time (days)	t_s	4.0	2.4	4.8	4.0	4.0	$\Sigma t_s = 19.2$
Total production time (days)		44.4	34.7	35.1	70.2	24.2	208.6
Production cycle	T_o	Length of production cycle = 208.6 × 1.05 = 219 days					

Table 6

INTERIM LONG CYCLE PLAN

Product		1	2	3	4	5	6	Remarks
Lot Size	Q	5050	6060	7570	9090	10100	22700	Consumption period $T_{c1-5} = 252$ days $T_{c6} = 452$ days
"p test"		√	√	√	x	x	√	
No. of lots		1	1	1	2	2	1	
Production time (days)	T_p	50.5	40.4	37.8	82.6	25.2	81.1	Totals $\Sigma T_p = 317.6$
Set-up time (days)	t_s	4.0	2.4	4.8	4.0	8.0	8.0	$\Sigma t_s = 31.2$
Total production time (days)		54.5	42.8	42.6	86.6	33.2	89.1	348.8
Production cycle	T_o	Length of production cycle 348.8 × 1.05 = 366 days.						

In both cases two lots per cycle were selected in order to avoid excessive set-up times.

(*d*) Assuming a uniform increase in production rate is to be adopted for all products, the increase can now be calculated.

For the long cycle—see Table 6—The total production time (including the safety allowance) is 366 — 31.2 × 1.05 = 333.2 days. This period should be reduced to 252 — 31.2 × 1.05 = 219.2 days. The increase should be by the ratio $\frac{333.2}{219.2} = 1.52$.

For the short cycle—see Table 5—The total production time (including the safety allowance) is 219 — 19.2 × 1.05 = 198.8 days. This period should be reduced to 202 — 19.2 × 1.05 = 181.8 days. Hence the increase is by the factor $\frac{198.8}{181.8} = 1.09$.

Now that the amount by which production should be boosted has been found, the modified version of the solution can be stated, as shown in Table 7. Note that this modification does not affect the lot sizes, the only change being in the production times.

(*e*) The main effect of increased plant dapacity on the lot sizes is expected in the long cycle, where production rates have been increased by 52%. As the suggested two-cycle plan in Table 7 is based on the normal production rates quoted in Table 2, it is necessary to ascertain either that this plan is still valid or to modify it in the light of the new data. Normally a check on one product may be enough to indicate whether the effect is likely to be marked. The minimum-cost-lot-sizes and production ranges for the case under consideration have been re-calculated and when these (shown in Table 8) are compared with the figures in Table 2, it is evident that the changes are very slight and hence the proposed solution in Table 7 is unaffected.

(*f*) The "p test" and the " cycle test " have been applied with satisfactory results, as shown in Table 7. All the lot sizes fall within the production ranges and the production cycle is geared to the demand.

(*g*) Having now satisfied all the requirements and limitations, which were imposed at the outset, the only problem left is the formulation of the final production schedule. When only one cycle has to be scheduled, during which each product is produced only once, the solution is straightforward, since the gearing of production to consumption is ensured when the formula for optimising the return of the profit in a multi-product programme is applied. The order in which the products should be manufactured is immaterial, as long as the same order is kept in every cycle.

However, when cycles are not identical, and especially when some products have to be produced more than once in one cycle, the scheduling may present some difficulties. The main problem is then to ensure that while each product should always be in stock, this stock should not be excessive when manufacture of the product is resumed, otherwise high carrying costs will be incurred. In some cases it may be necessary to introduce some modifications in the lot sizes, mainly where quantities which have to be divided into several lots are concerned. It has been decided, for instance, to manufacture product 4 in two equal lots, but this decision was an arbitrary one and it is possible to divide the quantity for this product into two unequal lots, if thereby a more satisfactory schedule can be obtained.

The final schedule for the plan as suggested in Table 7 is shown in Figure 9. The set-up time and the safety allowance are represented together as total setting period T_s (e.g., for product 1 in the short cycle $T_s = 4.0 + 1.9 = 5.9$ days). The change in stock is plotted for each product in order to facilitate control of stock levels throughout the cycle.

Thus, it has been shown that the method of increased plant capacity offers a means to master a pro-

duction load which would be impossible to meet with existing facilities. It, must, however, be borne in mind that increased capacity may affect the given data of machine set-up costs and constant costs per piece. Introduction of new equipment or special purpose machines and increased labour charges for overtime are only two factors which are likely to affect the issue and which may have to be taken into account.

4. Modify the requirements

If it is impossible to add or replace machinery to increase the output capacity of the plant, or if it is undesirable for any reason to employ overtime or shift work, the former method cannot be applied and we are faced with the problem of tackling the demands with the production rates specified in Table 2. It has already been stated that existing machines and facilities are inadequate to cope with the rate of consumption and, therefore, the load as presented by the first solution in Table 4 will have to be relaxed. This can be done in one or both of the following ways :

(*a*) Delete one or more of the products from the production plan in order to shorten the production cycle. The gap between the consumption period and the production cycle in Table 4 is 70 days and it would appear that elimination of product 4 or two other products will be necessary,

(*b*) Modify the requirement that all the products must always be in stock. It would be unreasonable to assume that a relaxation of this

Table 7

A TWO-CYCLE PRODUCTION PLAN (INCREASED PLANT CAPACITY)

Product		1	2	3	4		5		6	Remarks
Long Cycle										
Lot Size	Q	5050	6060	7570	4545	4545	5050	5050	22700	$T_{c1-5} = 252$ days
" p test "		√	√	√	√	√	√	√	√	$T_{c6} = 454$ days
Production rate (units/day)	a_p	152	228	304	167		608		426	
Production time (days)	T_p	33.2	26.6	24.9	27.2	27.2	8.3	8.3	53.3	$\Sigma T_p = 209.0$ days
Set-up time (days)	t_s	4.0	2.4	4.8	2.0	2.0	4.0	4.0	8.0	$\Sigma t_s = 31.2$ days
Safety allowance (days)		1.9	1.4	1.5	1.5	1.5	0.6	0.6	3.1	
Total production time (days) (including allowance)		39.1	30.4	31.2	30.7	30.7	12.9	12.9	64.4	$T_o = 252.3$ days
" Cycle test "				$T_o = T_{c1-5}$		√				
Short Cycle										
Lot Size	Q	4040	4850	6060	3640	3640	8090		—	$T_c = 202$ days
" p test "		√	√	√	√	√	√			
Production rate (units/day)	a_p	109	164	218	120		436			
Production time (days)	T_p	37.1	29.6	27.8	30.4	30.4	18.5			$\Sigma T_p = 173.8$ days
Set-up time (days)	t_s	4.0	2.4	4.8	2.0	2.0	4.0			$\Sigma t_s = 19.2$ days
Safety allowance (days)		2.1	1.6	1.6	1.6	1.6	1.1			
Total production time (including allowance) (days)		43.2	33.6	34.2	34.0	34.0	23.6			$T_o = 202.6$ days
" Cycle test "				$T_o = T_c$		√				

Table 8

THE EFFECT OF INCREASED PLANT CAPACITY ON THE PRODUCTION RANGES

Product	1	2	3	4	5	6
Long Cycle						
γ	.132	.105	.099	.214	.066	.118
Min. cost-lot-size	5610	5650	6190	3600	6660	20400
Production range	4100—7700	4130—7750	4520—8480	2310—5610	4870—9130	14900—28000
g_1	0.911					
Short Cycle						
γ	.184	.147	.138	.299	.092	—
Min. cost-lot-size	5550	5630	6140	3510	6610	—
Production range	4050—7610	4110—7720	4480—8410	2250—5480	4830—9060	—
g_1	0.617, but 0.73 has to be selected.					

Table 9

MODIFIED PRODUCTION PLAN EXCLUDING PRODUCT 4

Product		1	2	3	5	6	Remarks
Lot size	Q	5620	6750	8440	11250	14050	T_c = 281 days
"p test"		√	√	√	x	x	
No. of lots		1	1	1	2	Q too small	
Production time (days)	T_p	56.2	45.0	42.2	28.1	50.2	ΣT_p = 221.7 days
Set-up time (days)	t_s	4.0	2.4	4.8	8.0	8.0	Σt_s = 27.2 days
Total prod. time (days)		60.2	47.4	47.0	36.1	58.2	248.9 days
Production cycle	T_o	248.9 × 1.05 = 261 days					

requirement could be applied to all products (in which case the "cycle test" is immaterial and the production plan would consist of producing each product in turn at its minimum-cost-lot-size), but even if it can be tolerated for one or two products, the plan could be more easily formulated. From Table 4, however, it is evident that the production cycle is so long in relation to the production period, that reducing the production level of one or two products is not going to help.

The question which products are absolutely indispensable to the organisation and which may be deleted if need be, is obviously connected with a great many factors, such as competition in the market, legal or moral obligations by the firm to produce specific articles, technical or consumer relation between products, profitability of the products, future trends of consumption indicated by market research, future policies of the firm for specialisation or expansion, and so on.

Supposing in our case it was decided better to dispense with product 4 rather than with two other products. An interim solution replacing Table 4 can be worked out. Using the data in Table 3 and excluding product 4,

$$\Sigma\, s/s_1 = 14.8$$
$$\Sigma\, K\alpha^2/K_1 = 14.34$$
$$\therefore g_1 = \sqrt{\frac{14.8}{14.34}} = 1.015$$

The modified plan is given in Table 9.

The "p test."—Products 1 and 2 comply with this test. The quantity for Product 3 deviates so little from the production range (by 50 pieces) that it does not seem justified to divide it ; indeed in this case a division to two lots will cause a more marked deviation. Product 5 has to be manufactured more than once during the cycle. In view of the arguments given in section 2, the production range may probably be relaxed in such a way that only one lot per cycle need be produced. For the sake of illustration we shall, however, prescribe two lots, in strict accordance with the production range cited in Table 3. The quantity for product 6 is again far too small and a two cycle system is required.

The "cycle test."—It is clear from Table 9 that elimination of product 4 has served the purpose of bridging the gap between the consumption period and the production cycle. In fact we have now 20 extra days which are available for production.

A two-cycle plan.

The application of the "p test" to product 6 has shown the necessity for a two-cycle plan. The 20 available days in the cycle suggested in Table 9 could be used to manufacture more of product 6 to satisfy the demand for it during two cycles, the short cycle excluding product 6 altogether. The procedure to be followed is somewhat similar to that of the increased plant capacity method :

(*a*) Find the consumption period of the short cycle.
(*b*) Add the two consumption periods and compute the quantity required for product 6.
(*c*) Determine if the additional required amount complies with the available production capacity in the long cycle. If it does not, transfer partial production to the short cycle, if capacity for the purpose is available, or modify the short cycle.
(*d*) Outline the production plan.
(*e*) Apply the "p test" and determine the number of lots per batch. Apply the "cycle test."
(*f*) Introduce adjustments into the plan, if necessary.

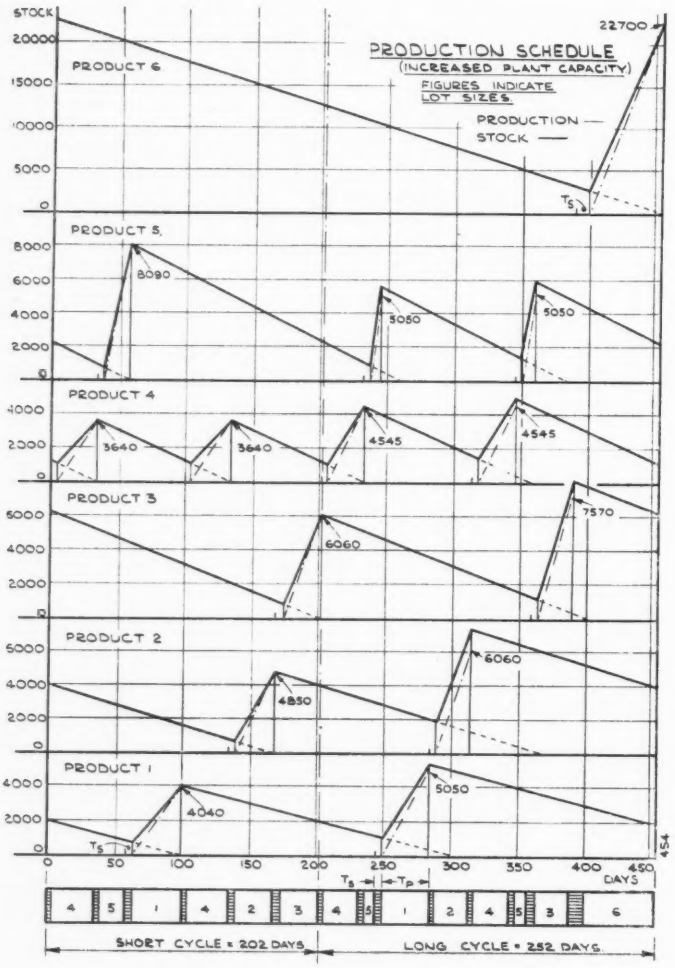


Fig. 9. Production schedule (increased plant capacity).

TABLE 10

A TWO-CYCLE PRODUCTION PLAN (MODIFIED REQUIREMENTS)

Product		1	2	3	5		6	Remarks
Long Cycle								
Lot size	Q	5620	6750	8440	5625 (4800)	5625 (6450)	24150	$T_{c1-5} = 281$ days $T_{c6} = 483$ days
"p test"		√	√	√	√	√	√	
Production time	T_p	56.2	45.0	42.2	14.1 (12.0)	14.1 (16.1)	69.0*	*for 19350 pieces
Set-up time	t_s	4.0	2.4	4.8	4.0	4.0	8.0	
Safety allowance		3.0	2.4	2.3	.9 (.8)	.9 (1.0)	3.8	
Total prod. time (including allowance)		63.2	49.8	49.3	19.0 (16.8)	19.0 (21.1)	80.8	$T_o = 281.1$ days
"Cycle test"		$T_o = T_{c1-5}$ √						
Short Cycle								
Lot size	Q	4040	4850	6060	8090			$T_{c1-5} = 202$ days
"p test"		√	√	√	√			
Production time	T_p	40.4	32.3	30.3	20.2		17.1**	** for 4800 pieces
Set-up time	t_s	4.0	2.4	4.8	4.0		—***	***production continued from long cycle
Safety allowance		2.2	1.7	1.7	1.2		0.9	
Total prod. time (including allowance)		46.6	36.4	36.8	25.4		18.0	$T_o = 163.2$ days
"Cycle test"		$T_o < T_{c1-5}$ √ Available time: 202 — 163.2 = 38.8 days.						

(*g*) Determine the final production schedule.

We shall now follow this procedure in an attempt to define an acceptable solution :—

(*a*) From Table 3, it can be found that for the short cycle (in which products 1, 2, 3, 5 are produced) $g_1 = 0.705$. As this factor will yield for product 1 a quantity which is smaller than the production range, the value $g_1 = 0.73$ has to be selected leading to quantities as shown in Table 5 (disregarding product 4) and a consumption period of 202 days.

(*b*) and (*c*) The consumption periods of the two cycles amount to 281 + 202 days = 483 days. Hence 483 × 50 = 24150 pieces of product 6 have to be manufactured in the long cycle, an addition of 10100 pieces, corresponding to 36.1 days of production. As only 20 days are available in the long cycle, (actually, only 19 if the 5% safety allowance is to be accounted for), production of No. 6 will have to continue for 17.1 days in the short cycle. From Table 5 it is clear that if product 4 is missing from the plan, the production cycle will be shorter than the consumption period and such an overflow into the short cycle, using some of its available production capacity, is possible.

(*d*) The production plan is now outlined in Table 10. As the manufacture of product 6 in the two cycles is, in fact, carried out in one continued period, the set up time was taken only once into account.

(*e*) and (*f*) Application of the "p test" and the "cycle test," as shown in Table 10, gives satisfactory results. The production cycle in

both cycles does not exceed the consumption period, and in fact in the short cycle we have 38.8 days in hand, which is available for meeting additional orders. This time, may be used, for example, to produce product 4, but it is evident that the quantity which can be produced will be sufficient to satisfy only a fraction of the demand for this product. Accounting for the safety allowance and the set-up time, the available time for production is 35.0 days, during which 3850 pieces of product 4 can be produced, and this figure passes the "p test." It will however, cover a demand period of only 107 days, i.e., 22.1% of the total demand during the two cycles. At this stage no adjustment to the plan is necessary, as it complies in all details with our modified conditions.

(*g*) Scheduling is attempted on the principles discussed previously, and as in the case of Figure 9, it is found easier to start with the short cycle. The position of product 4 in this cycle is immaterial, as it is not bound by a consumption period to what occurs in the long cycle, and this fact offers a certain amount of flexibility. Another arbitrary decision that may be modified at this stage is the division of the quantity relating to product 5 to lots. Suppose we determine that two equal lots (5625 pieces each as shown in Table 10) should be adopted and that production should proceed by the following order : Short cycle—6 (finish) 1, 5, 2, 3, 4 ; long cycle—1, 5, 2, 3, 5, 6 (start). If we plot the change in stock levels, in a similar way to Figure 9, we shall find that too much stock is carried over to the last production of product 5. Although this does not result in stocks for product 5 ever exceeding the ceiling of the production range, it would be better to divide the quantity for this product to unequal lots, say 4800 and 6450 pieces respectively, and thus reduce considerably the stock carried over. These figures, as well as the respective production times for the new lots, are shown in brackets in Table 10 and are taken as the basis for Figure 10, in which the final schedule is given.

Figure 10 suggests that the distinction between two separate cycles in the production plan is somewhat artificial, as the overflow of production from one

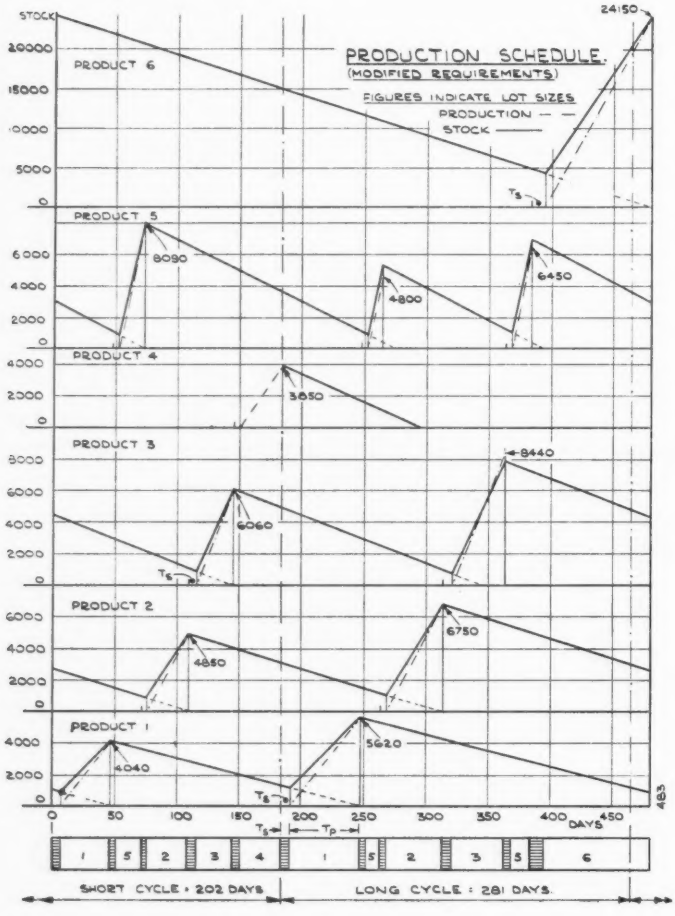


Fig. 10. Production schedule (modified requirements).

Table 11

TOTAL COSTS PER PIECE

Product		1		2		3		4		5		6	
		Y	Inc. %	Y	Inc. %	Y	Inc. %	Y	Inc. %	Y	Inc. %	Y	Inc. %
Minimum costs (Ym.)		5.08		2.24		7.18		12.86		17.82		8.97	
Increased Capacity Method (Table 9)	Long cycle	5.09	0.2	2.24	—	7.20	0.3	12.89	0.2	17.88	0.3	8.99	0.2
	Short cycle	5.14	1.2	2.25	0.4	7.18	—	12.86	—	17.86	0.2	—	
	Av. for schedule	5.11	0.6	2.245	0.2	7.19	0.1	12.88	0.2	17.87	0.3	8.99	0.2
Modified Requirements Method (Table 10)	Long cycle	5.09	0.2	2.25	0.4	7.24	0.8	—		17.86	0.2	9.01	0.4
	Short cycle	5.14	1.2	2.25	0.4	7.18	—	12.86	—	17.86	0.2	9.01	0.4
	Av. for schedule	5.11	0.6	2.25	0.4	7.21	0.4	12.86	—	17.86	0.2	9.01	0.4

cycle to the other makes their boundaries difficult to define. Nevertheless, the outline as given in Table 10 is useful, since it can serve as a basis for planning any changes which may be envisaged in the production schedule.

The flexibility of this method is obviously tied up with the nature of the relaxations of the original requirements that can be made, and the looser these are, the simpler the procedure and the less time taken to arrive at a satisfactory plan. It has, however, been shown above that even with the imposition of many restrictions the method is workable and clearly indicates when and what kind of decisions have to be taken.

The schedules which are finally defined by the use of the two methods described above are strikingly similar, as shown in Figures 9 and 10. The main difference between them is the treatment of product 4, which in the second method was sacrificed as being the least important in the production plan.

As we have been trying to produce the articles at the point of minimum costs per piece, it is interesting as a final check, to see how the two proposed schedules deviate from this objective. The comparison between the actual production costs and the minimum costs is made in Table 11, and it appears that the costs do not increase by more than 0.6% in the case of product 1 and the increase is appreciably smaller for the other products.

In a two-cycle production plan if a quantity is placed in the extreme production ranges in one cycle, the effect of the corresponding quantity in the other cycle would be to damp the average increase in cost during the whole schedule. This is a good argument in favour of relaxing in some cases the "p test" in a two-cycle system, because even if in one cycle too high variable costs are incurred, the average throughout the schedule may still be within the original prescribed limits. The costs of product 1, for instance, will reach 5.14 shillings per piece in the short cycle and this is the limit imposed by the initial condition that the variable costs should not increase by more than 5% (selection of the lot size for product 1 in this cycle has in fact been governed by this limitation when g_1 was ascertained). However, the average costs per unit for the whole schedule is 5.11, resulting in an increase of variable costs of only 2.8%. Hence a lower value for g_1 could be acceptable and the production cycle could be shortened without violating the initial p limitations.

Conclusion

The object of this Paper is to show how computation of lot-sizes can be applied to problems arising from scheduling of batch production. The analysis described offers a systematic procedure pointing out the decisive issues that are involved and the steps that have to be taken. It also provides a comparatively simple method for formulating a final satisfactory production schedule, as well as a useful guide when changes in the schedule have to be introduced. One of the main assumptions in this analysis is that manufacture of one product follows the completion of a batch of another product, that is, there is no overlap of production times. The problems arising when simultaneous manufacture of various products takes place are far more complicated and no attempt at a solution was made in this Paper, but many such cases may successfully be treated as approximations by the methods outlined above.

APPENDIX

Notation.

B = average storage costs per piece per unit time.
I = carrying costs per piece per unit time.
K = carrying costs factor.
Q = quantity produced.
Q_e = economic lot-size.
Q_m = minimum costs lot-size.
Q_p = maximum profit lot-size.
T_c = consumption period.
T_o = total production cycle.
T_p = production period.
Υ = total production costs per piece.
Υ_m = minimum production costs per piece.
Υ' = sales price.
a_c = consumption rate (units per unit time).
a_p = production rate (units per unit time).
c = constant costs per piece.
i = interest rate per unit time (expressed decimally).
p = a variable costs ratio $\frac{\Upsilon - c}{\Upsilon_m - c}$
p' = a ratio $\frac{\Upsilon' - c}{\Upsilon_m - c}$
q = $\frac{Q}{Q_m}$
s = preparation costs, including machine set-up.
t_s = setting time before production.
u = a ratio $\frac{c}{KQ_m}$
α = ratio of the consumption rate of a product to the consumption rate of product No. 1.
γ = ratio of consumption rate to production rate $\frac{a_c}{a_p}$

Other symbols are explained in the text.

Minimum-cost-lot-size.

The total cost function is

$$\Upsilon = c + \frac{s}{Q} + KQ \tag{1}$$

When Y is minimum, the lot-size is [8]

$$Q_m = \sqrt{\frac{s}{K}} = \sqrt{\frac{2a_c s}{I(1+\gamma)+2B}} \tag{2}$$

where the carrying cost factor $K = \frac{1}{a_c}\left[\frac{I}{2}(1+\gamma)+B\right]$ (3)

The minimum costs per piece are

$$\Upsilon_m = c + \frac{2s}{Q_m} = c + 2KQ_m \tag{4}$$

Special cases : (1) When B, γ are negligible, Camp's [1], [5], formula (1922) is obtained :

$$Q_m = \sqrt{\frac{2a_c s}{I}} \tag{5}$$

(2) When γ is small or deleted for ordering purposes, the so-called inventory formula is obtained :

$$Q_m = \sqrt{\frac{2a_c s}{I+2B}} \tag{6}$$

Example : Given — c = 9.4 shillings per piece ; rate of production 2500 per day ; rate of consumption 500 per day ; set-up costs £50 ; storage costs 1.5×10^{-3} shillings per piece/day.
Interest charges are 8%.
Solution : Assume 300 working days a year,

$\therefore i = \frac{8}{100}\frac{1}{300} = 2.67 \times 10^{-4}$ and $I = ic = 2.5 \times 10^{-3}$ per piece/day.

The minimum-cost-lot-size by (2) :

$$Q_m = \sqrt{\frac{2 \times 500 \times 1000}{2.5 \times 10^{-3} \times 1.2 + 2 \times 1.5 \times 10^{-3}}}$$

= 13000 pieces.

and by Camp (5) : $Q_m = \sqrt{\frac{2 \times 500 \times 1000}{2.5 \times 10^{-3}}}$

= 20000 pieces.

The inventory lot by (6):

$$Q_m = \sqrt{\frac{2 \times 500\ 1000}{2.5 \times 10^{-3} + 2 \times 1.5 \times 10^{-3}}}$$

= 14200 pieces.

Production of Q_m also yields maximum return (or ratio of profit to investment).

$$\frac{\text{Profit}}{\text{Investment}} = \frac{\Upsilon' - \Upsilon}{\Upsilon}$$

At Q_m the value of this function becomes $\frac{p' - 1}{1 + \frac{u}{2}}$

Deviations from Q_m.

The allowable increase in variable costs above the minimum variable costs is described by the factor p. Lot sizes Q_I and Q_{II} (Fig. 5) are the limits of the production range, in which any quantity will not involve higher production costs per piece than the value defined by p. These limits are computed from :

$$\left.\begin{aligned} Q_I/Q_m &= p - \sqrt{p^2 - 1} \\ Q_{II}/Q_m &= p + \sqrt{p^2 - 1} \end{aligned}\right\} \tag{7}$$

Maximum profit lot-size.

The profit function $Q(\Upsilon' - \Upsilon)$ is maximum at

$$\left.\begin{aligned} q &= p' \\ \text{or } Q_p &= p'Q_m \end{aligned}\right\} \tag{8}$$

when the profit is $Q_m \Upsilon_m p' \frac{p' - p}{1 + \frac{u}{2}}$

Economic lot size.

The rate of return is proportional to $\frac{1}{T_c}\frac{\Upsilon' - \Upsilon}{\Upsilon}$, which reaches maximum [9], when

$$q^4 - 4p'q^3 + 2(1 - up')q^2 + 2uq + 1 = o \tag{9}$$

The solution of q depends on the parameter u and lies between

$$q = \frac{p^2}{p'} \text{ or } Q_e = \frac{p^2}{p'} Q_m \text{ (applicable when } u \to o) \tag{10}$$

and $q = \frac{1}{p'}$ or $Q_e = \frac{1}{p'} Q_m$ (applicable when $u \to \infty$) (11)

(*concluded on page* 582)

SIMPLIFICATION AND STANDARDISATION FOR AUTOMATION

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and

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From 1926-1929, *he was Assistant Chief Designer at the Ursus Engineering Works, Warsaw, and subsequently became Works Manager and Deputy Technical Director of Andre Citroen, Warsaw branch, where he remained until* 1932. *For the next two years he was Engineer in charge of Development of National Production of the Polish State Engineering Works. In* 1934, *he turned to Consultancy and became established as a Consulting Engineer, first in Warsaw and then in Paris, until the outbreak of the Second World War, when he came to England, and joined the Department of Tank Design of the Ministry of Supply.*

In 1948 *Mr. Brisch founded the firm of Consultants, E. G. Brisch and Partners, of which he is Chairman and Managing Director.*

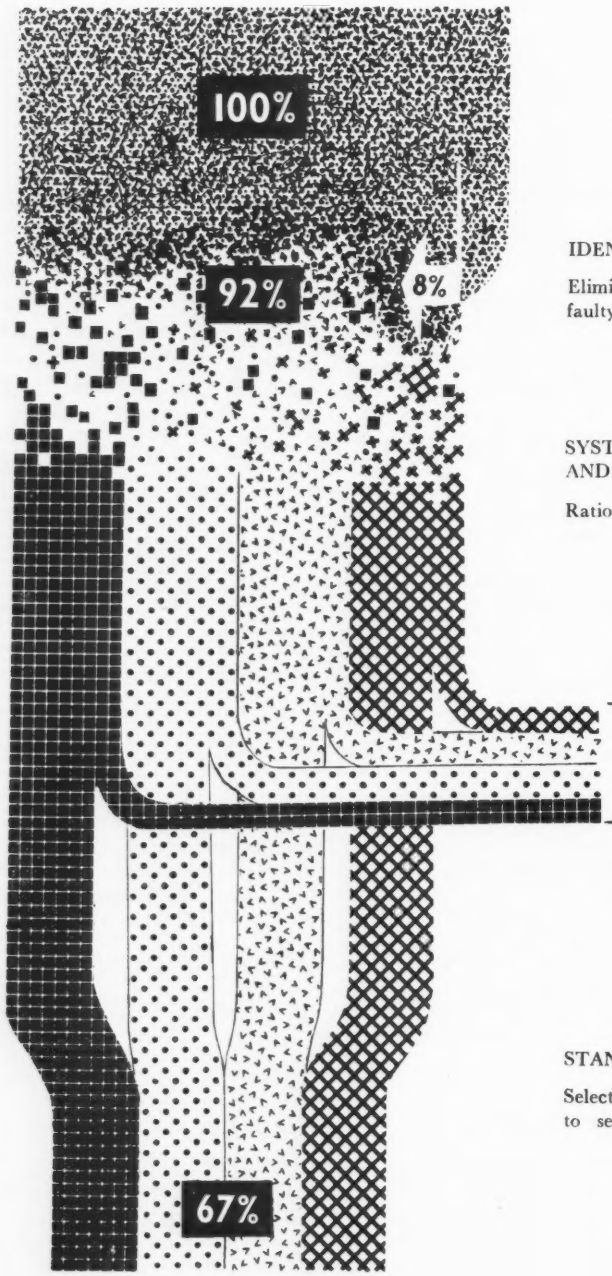
Mr. Geoghegan, who is Sales and Development Director of E. G. Brisch and Partners, graduated at Cambridge in 1932, *with honours in Mechanical Sciences Tripos. He served an engineering apprenticeship with Mather & Platt, Manchester, and then joined Fluidrive Engineering Ltd., to set up and manage an Experimental and Development Department.*

He served throughout the Second World War, attaining the rank of Lieutenant-Colonel, and was latterly seconded to the Department of Tank Design as liaison officer for the War Office on design modification and special requirements for Churchill tanks.

After the War, Mr. Geoghegan was a Management Consultant with Personnel Administration Ltd., until 1951, *becoming a Senior Consultant in* 1948. *In* 1951, *he went to Ferguson Bros., Carlisle, as General Manager, and subsequently joined E. G. Brisch and Partners in* 1953.

"TIME spent in reconnaissance is seldom wasted" is an age-old Army adage which has rarely, if ever, failed to bear fruit. In industry, however, it is far from true. A good deal of time can be, and is being spent in reconnoitring, searching and trying to find, with the result that much time and money is wasted. It can be a most expensive operation. The occasions on which there is a need to find what has been done before so as to avoid the needless creation of a new part or tool, or the procurement of a new material or bought-out commodity, are legion. The need, of course, is the outcome of the determination or of a policy not to create any unnecessary operation or function and to avoid the introduction of any variety which is unnecessary. The advent of automation has made the need for variety control, and with it a logical and economic approach to simplification and standardisation, an essential prerequisite if the fullest advantages of the automatic factory are to be obtained.

INITIAL VARIETY — AUTOMATION IMPRACTICABLE



IDENTIFICATION

Elimination of duplications due to faulty nomenclature and obsolete items.

SYSTEMATICAL CLASSIFICATION AND CODING

Rational grouping and arrangement.

SIMPLIFICATION

Deliberate elimination of unnecessary items.

STANDARDISATION

Selection and control of preferred items to secure their maximum utilisation.

USEFUL VARIETY — AUTOMATION PRACTICABLE

Perhaps the most important factor, which will decide whether a new management technique or method of manufacture is worthy of examination and subsequent implementation, lies in the contribution that it will make to increasing productivity and reducing manufacturing costs, with the ultimate possibility of these being reflected in selling prices. Considering the potentialities of simplification and standardisation for increasing productivity and reducing costs, these techniques have not had the attention which they merit.

Reluctance to apply new methods is not infrequently due to the lack of a clear understanding of their significance and definition and to the absence of a satisfactory and proven method of approach. Their true meaning is not always appreciated and frequently a number of people discussing a new technique or management subject may find that they are not "talking the same language".

Definitions of automation

Various definitions have been given for "automation", some of which are little more than a high-faluting name for mechanisation capable of creating a mental picture of a robot-controlled factory. The following, even though some may regard it as an over-simplification, offers a definition of the automation concept.

The time which elapses between the placing of a material or part into process and the time when that part is finished or the product assembled ready for dispatch, is made up of two periods — that during which work is done on the material or part to change its shape, form or finish and that during which no such work is done but the item is either waiting for the next operation, e.g. while being set up in the machine, or is in the process of being moved from one work place to another. The former may be described as the productive time and the latter as the non-productive time.

Specialisation through the use of special purpose machines designed to carry out specific operations, or to manufacture a narrow range of products, has enabled manufacturing costs to be reduced by cutting productive time. Automation, by broad definition, is complementary to specialisation in reducing non-productive time, in that it simplifies and facilitates the handling of materials and parts between operations and minimises machine setting time and idle time on the shop floor. The economic justification and overall effectiveness of automation are strongly influenced by the variety of materials or parts which have to be manufactured and handled, since unnecessary variations or differences in these items will prevent the ideal cycle of automation being attained.

Automation, therefore, whether expressed in the form of electronically controlled plant or in the form of transfer machines, will only yield the optimum results when, for the application under consideration, the variety of parts, materials and even tools have been reduced to a minimum. Simplification, i.e. the process of reducing the number of varieties made or procured, and standardisation, the process of securing the maximum utilisation of preferred varieties having agreed standards of performance, quality, composition or dimensions, are essential requirements for the automatic factory. The many advantages which arise from automation, such as saving in direct labour, reduction of work-in-progress, better production control, greater machine utilisation and reduced machine-setting time, will be lost unless a clearly defined policy of simplification and standardisation has been laid down and the means devised to ensure its effective implementation and application. The very concept of the automatic factory will be greatly minimised or even destroyed if an excessive variety of processes and operations are necessary.

Simplification and standardisation — let me emphasise here that standardisation does not mean uniformity — heaven forbid that we should all look alike or even wear clothes which look the same! — can be considered at any stage of the production process from the design of the component parts and tools, through the purchasing of the materials and bought-out commodities to the planning and production of the finished product. In many cases, an analysis of sales demands, product profitability and distribution costs, can lead the way to product simplification and such an approach is one with which many companies are by no means unfamiliar. But less attention has been given to the simplification and standardisation of the materials, components and tools which are required to produce the optimum or agreed range of finished products. The creation of a new model or product in the Design Office often results in the finished article being more complex than is necessary to achieve the required performance or to satisfy the customer, and the component parts, materials and tools utilised for that purpose are often of a greater variety than necessary.

One of the main causes of excessive variety is the absence of accurate identification and the lack of simple and foolproof means to locate past designs. Inaccurate descriptions, ambiguous titles and piece part nomenclature and meaningless numbers give rise to wasted designs, superfluous stock holdings and unnecessary machine setting times.

As a result, not only are the many advantages of automation not obtained, but the application of automation to a given manufacturing or assembly operation may become completely uneconomic.

The logical approach

Classifying and coding is only gradually becoming recognised as a logical and systematical approach to simplification and standardisation and many firms, realising their need, have taken steps to arrange and sort items in catalogue form, of which a standards catalogue is an example. Many have been unsuccessful through failure to base their standards catalogues and standardisation programmes on sound principles. The first essential is a clear and well-defined overall plan to form the classification framework. This necessitates the determination of the main headings,

for example, primary materials, bought-out commodities, designed parts, assemblies, finished products, tools and plant, with a clear definition of each. Fig. 1 gives an example of this.

In establishing and, more important, in developing the classification as a tool for simplification and standardisation, each item must be accurately and sufficiently identified according to its nature. It is clearly not possible to reduce variety without knowing precisely what variety exists. It is in this respect that faulty descriptions and trade names are found to be the cause of closely similar and even identical items being concealed. For example, Tufnol Kite, Bakelite B152/1, Texolex ZA and Pirtoid MP.31, are all laminated plastic synthetic resin bonded paper base tubes complying with B.S.1314 Type A. Also, the trade names of F.S.T., S.F.20, Evershyne B.S. and Maxilvry are four among a number of proprietary names which are all stainless steels complying with B.S.970 EN58A.

Such terms as "miscellaneous", "sundry", and "etc." creep into vocabularies and catalogues and sometimes become the biggest individual section.

Classification

The next step is classification, i.e. the grouping or arranging of similar items according to their common features and subdividing them by their essential differences. Even with accurate identification, the classification can be quite ineffective unless there has been a sound analytical approach to determine what are the requirements of a good classification system. The classification of items according to the arbitrary names that they acquire because of the functions or assemblies for which they are designed, frequently creates instead of prevents unnecessary items. It is essential, therefore, that

(a) items should be classified according to those characteristics or features which are permanent;
(b) the classification should be such that an item can be found in one place and one place *only*.
(c) there is adequate room in the framework to allow for the introduction of new items without causing the classification to break down.
(d) the classification must be designed from the point of view of the user.

Perhaps the simplest day-to-day example of this is a game of Whist or Bridge at which each player is dealt a hand of 13 cards. Most people, when asked what is the first thing they do when they pick the cards up off the table, would say that they sort them. A little reflection will show that this is not the case, but that the first thing they do is to examine what they have got. In other words, they are identifying what they have in their hands. They are quick enough to complain if they had been dealt a Joker! Only when they *know*, i.e. have identified, what they have got, can they start to arrange or sort their hand and although each of the four players may sort his cards differently, they sort them from their individual points of view, according to the permanent characteristics of each card, e.g. colour, suit and value,

THE MAIN CLASSES

0 Organisation and operations
1 Primary Materials
2 Bought-out Commodities ("shelf" items)
3 Components (to user's own design)
4 Sub-assemblies and assemblies (products)
5 Tools and portable equipment
6 Plant and machinery
7 Buildings, services, utilities
8 Scrap, Waste
9 Reserved

Fig. 1.

with the common object of being able to find quickly what they want, when they want it. It is in such a way that a systematical classification enables any organisation to compare what they possess with what they want. While accurate descriptions are essential to ensure correct identification, their phrasing and even length may make comparisons unsatisfactory and tedious. For this reason it is necessary to symbolise the classified descriptions by a code (compare the number in the corner of the playing cards), which immediately reveals similarities and interchangeabilities. Many so-called codes found in industrial firms are often no more than meaningless and sequential numbers, whilst others are a mixture of letters and numerals mostly without significance, unequal in length and liable to break down owing to insufficient space being left to introduce new items within the range of numbers allocated. The code must, therefore, if it is to be the key to simplification, be easily understood and interpreted and be the means of controlling variety by enabling all proposed new items quickly to be compared with existing similar ones so that superfluous items can be eliminated and unnecessary designs prevented. The code numbers themselves should be wholly numerical, of constant length and each digit should carry a significance by virtue of its position and its value (see Fig. 2).

Consideration of types and sizes

It is at the classification stage that consideration should be given to those types and sizes of materials, bought-out parts or tools which, from the user's point of view, have the greatest potential use. Scheduling of the preferred types and sizes constitutes the first means of establishing company standards around which the designer is encouraged to design, and which can be used without seeking special authority. The remainder are the non-preferred types and sizes, the use of which must be discouraged, and which should be eliminated by using up in production or maintenance, re-processing or selling to the best advantage. Their re-ordering and restocking should be prevented. These schedules of preferred and non-preferred varieties thus express the company's policy on simplification "tailor-made" to their own particular requirements.

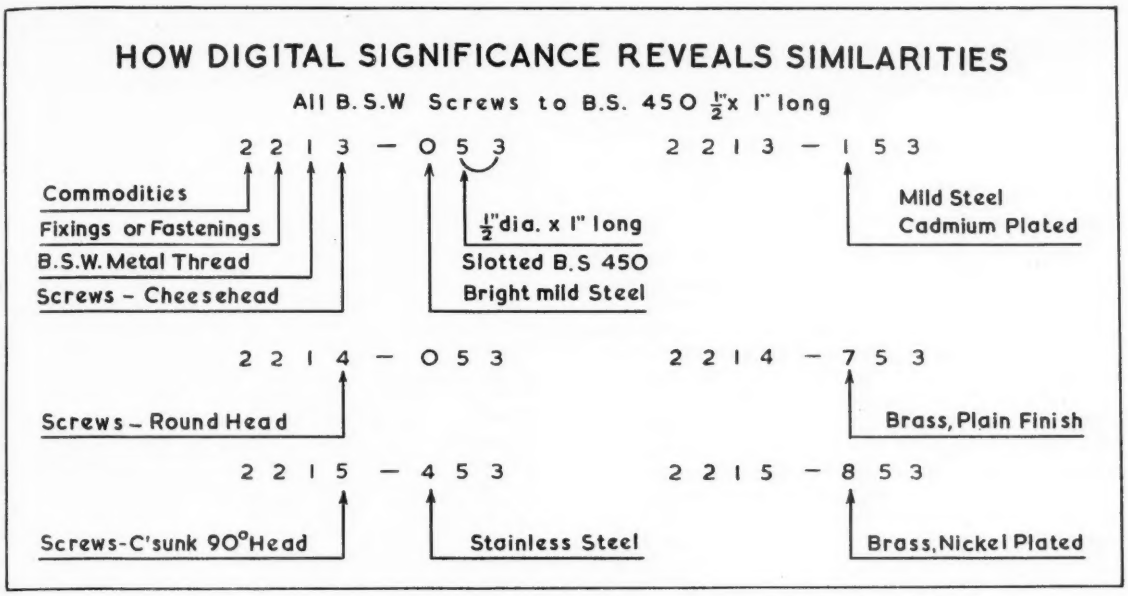

HOW DIGITAL SIGNIFICANCE REVEALS SIMILARITIES
All B.S.W Screws to B.S. 450 ½" x 1" long
2 2 1 3 — 0 5 3
Commodities
Fixings or Fastenings
B.S.W. Metal Thread
Screws – Cheesehead
½" dia. x 1" long
Slotted B.S 450
Bright mild Steel
2 2 1 3 — 1 5 3
Mild Steel
Cadmium Plated
2 2 1 4 — 0 5 3
Screws – Round Head
2 2 1 4 — 7 5 3
Brass, Plain Finish
2 2 1 5 — 4 5 3
Screws-C'sunk 90° Head
Stainless Steel
2 2 1 5 — 8 5 3
Brass, Nickel Plated

Fig. 2. Code number of the Brisch classification has a 'surname' of 4 digits, followed by a 'Christian name' of 3 digits.

SHEET 72

	Original No.		*Description*		*Brisch Code No.*		
S	74601	B	ELEC	TAPE	1756	203	
S	74602	B	DUREX	TAPE	1756	204	
S	74605	B	DUREX	TAPE	1756	205	
S	74573	3	PAPER	TAPE	1756	206	2=1
S	74603	B	PAPER	TAPE	1756	206	
S	74573	7	PAPER	TAPE	1756	210	2=1
K 8	92023	A	TAPE		1756	210	
S	74573	9	ADHESIVE	TAPE	1756	212	
S	74573	11	ADHESIVE	TAPE	1756	214	
S	74785		TAPE		1756	301	
S X K	1112		ADHESIVE	TAPE	1756	302	
S X K	1105		ADHESIVE	TAPE	1756	303	2=1
S	74783		ADHESIVE	TAPE	1756	303	
S	74780	A	ADHESIVE	TAPE	1756	304	
S X K	1106		ADHESIVE	TAPE	1756	305	3=1
S	74116		ADHESIVE	TAPE	1756	305	
S	74782	B	TAPE		1756	305	
S	74812	A	LASSO	TAPE	1756	501	2
S	74813	A	LASSO	TAPE	1756	501	3
S	74814		LASSO	TAPE	1756	501	4
S	74815	A	LASSO	TAPE	1756	501	5
S	74816	A	LASSO	TAPE	1756	501	6
S	74819		LASSO	TAPE	1756	501	9
K 8	91822	I S H	LASSO	TAPE	1756	501	2=1 9
S	74810	A	LASSO	TAPE	1756	501	10
K 8	9051S	107	LASSO	TAPE	1756	502	
S	74313		LASSO	TAPE	1756	502	2
S	74545		LASSO	TAPE	1756	502	2=1 2
S	74547		LASSO	TAPE	1756	502	4
S	74549		LASSO	TAPE	1756	502	5
S	74546		LASSO	TAPE	1756	502	6
S	74551		LASSO	TAPE	1756	502	9
S P K	1299		LASSO	TAPE	1756	502	10
S	74544		LASSO	TAPE	1756	502	4=1 10
S	74825		LASSO	TAPE	1756	502	10
K 8	9051S	110 C	BLK	TAPE	1756	502	10
S	74826		ADHESIVE	TAPE	1756	503	9
K 8	7291	2 D	LASSO	TAPE	1756	503	10
S	74683	B	LASSO	TRANSP	1756	504	
S P K	1241		PLAS	TAPE	1756	504	9
S P K	1241		LASSO	TAPE	1756	504	3=1 9
K 8	91822	15 H	LASSO	TAPE	1756	504	9

Fig. 3. Considerable duplication in stocks of insulating tapes was revealed in this tabulation converting the original meaningless numbers into significant Brisch code numbers; 42 items are here reduced to 30.

Only if designed around these principles and with these objectives in view, will classification and coding reveal whether the retention of certain items is justified ; whether there are duplications (see Fig. 3) ; whether there are redundant materials ; whether a component about to be designed does in fact already exist ; whether, if no existing component is suitable, a closely similar one can be used ; and whether existing tools can be used, or obsolete ones resuscitated.

Accumulation of numerous entries under the same heading is often a pointer to needless variety, but it must be emphasised that the work of simplification requires an analytical approach. For a storeholding point of view, stocks having a low rate of turnover are generally the ones which can most easily be dispensed with or reduced. On the other hand, those extensively used are not always the ones to be retained. The extent to which a firm's spare parts and maintenance service constitute a large proportion of their business may strongly influence the need to rationalise design, reduce existing variety and control future variety. Excessive variety will complicate and perhaps make insoluble the problem facing management in developing and applying factory automation.

Classification can therefore deal with and remove the fundamental causes of idle, redundant and obsolete stocks. Capital tied up in unnecessary stock is released, the rate of stock turnover is increased and the annual cost of holding stock reduced.

It is not only among the materials, bought-out commodities and small tools that are procured and stocked that unnecessary variety occurs, but also in the design of individual piece parts which are created as new products are designed and developed. Few firms will deny that closely similar and even identical parts are designed and produced within their own organisation because they have no foolproof means of quickly tracing *all* similar parts or their drawings, so as to be sure that there are no suitable ones already in existence.

WHAT'S IN A NAME ?

Pin	Latch	Roller spindle
Pin hinge	Button	Lever spindle
Peg	Stud	Armature stud
Locating peg	Rod	Pinion spindle
Dowel	Hinge rod	Slave spindle
Brush	Lock rod	Clutch roller
Valve cotter	Push rod	Counter shaft
Canopy rod	Valve rod	Reset spindle
Roller shaft	Plain rod	Straight pin
Pivot	Rivet	Armature stem
Brush	Spacer	Contact spindle
Plug	Post	Drain tap boss
Spindle	Bar	Piston rod pin
Stop	Dashpot rod	Handle stop pin
Roller	Valve stem	Pin push lever
Plunger	Flag pivot	Fuel pump tappet
Connector	Crank rivet	Kicker catch pin
Trunnion	Roller pin	Thrust collar pin
Electrode	Pin link	Carrier link pin
Pin pivot	Post mileage	Sanding valve
Pin anchor	Location pin	Valve cotter pin
Pin crank	Operating pin	Clutch toggle pin
Drive pin	Trip arm pin	Swing bolt pin
Pivot top	Pawl spindle	Pin-towing eye
Plain pin	Special pin	Wheel stud dowel
Dowel pin	Eyebolt pin	Water pump dowel
Wire pin	Bearing pin	Chain anchor dowel
Bond pin	Dividing bar	Jack leg plug
Sealing sleeve driving pin		Dowel for main bearing
Intercooler fitter dowel		Reset frame shop pin
Starting handle shaft pin		Breather hole plug
Distributor drive plain pin		Selector bar plug
Water pump driving pin		Governor weight spindle
Governor drive coupling pin		Connecting link rod
Manhanding bar knuckle jaw pin		Oil relief ball stop
Water pump spring collar peg		Float lever stud
Pump drive centre driving peg		Contact lever axle
Inlet rocker bracket oilway plug		Pin clamp plate
Armature cradle bearing rod		Pin mould holding
Connector moving oscillator coil		Motor drive spindle
Main spindle location pin		Sanding valve roller
Armature laminated rivet		

Fig. 4. The 111 names in this list are actual names found among the drawings of four different manufacturers and describe plain single diameter pins.

Classifying by design features

Many attempts have been made to group or classify designed parts under their titles or generic headings, such as pins, spindles, shafts, collars, brackets and levers. Standard terminology is not the solution to the problem, since no clear distinction can be given between a bracket and a support, a lever and a link, or a collar and a sleeve (see Fig. 4). Designed parts must be classified according to their design features. In some cases the predominant features may be shape ; in other cases, the name given to the part may clearly identify the item without any ambiguity, for example, a gearwheel, a nameplate or an impeller in a firm manufacturing centrifugal pumps. By classifying these parts according to their permanent basic characteristics and proceeding systematically from the general to the particular, small batches of closely similar drawings are brought together, irrespective of their existing names, functions, or assemblies for which they were designed. Through the medium of a numerical code, designed to symbolise these characteristics, and through the medium of a coded catalogue of all such drawings, which is the means of finding the code number of the part required, the designer is provided with a simple and foolproof method of locating *all* drawings of parts similar to the one he is about to design. Should a suitable one not exist, the availability of all similar parts, say, 10 - 15, enables the designer, where a new part has to be designed, to consider the possibility of the new design fulfilling, not only the new function, but also that of one or more of the existing parts, thereby

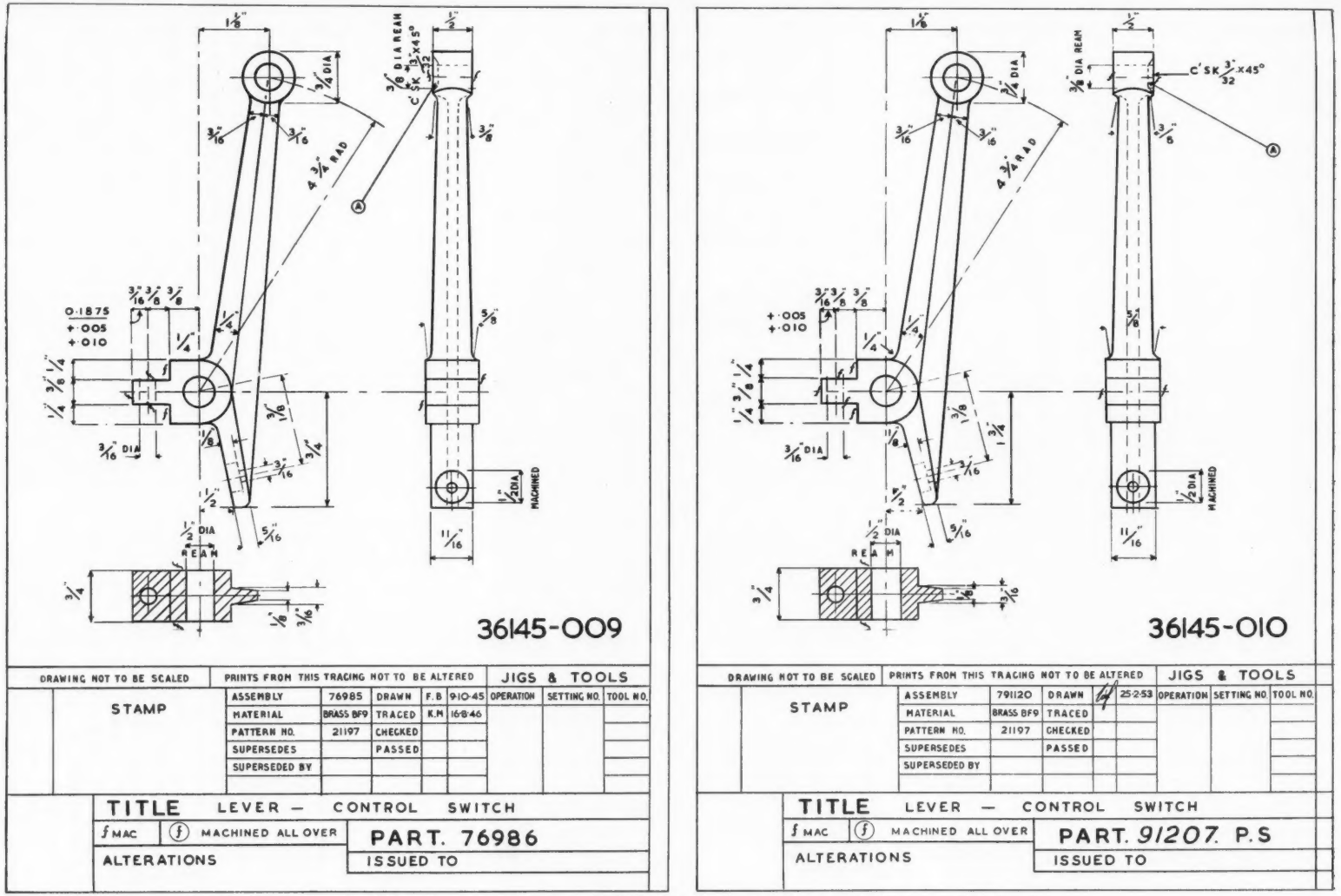


Fig. 5. This shows two components, identical in all respects except that one is left-hand and one is right-hand, by virtue of the countersinking shown at A. If the drawing of the first part could have been located, which was not possible under the original numbering, the first part could have been countersunk on both sides, thus making a second design and a second pattern unnecessary. The code number immediately reveals the similarities.

Fig. 6. An illustration of how stores layout can be improved by systematical Classification and Coding. These photographs show a stores before *(top photograph)* and after *(bottom photograph)* a simplification programme has been carried out.

enabling these to be eliminated (see Fig. 5). In addition, the possibility of modifying existing and obsolete tools to manufacture the new part can be considered, the cost of which would be considerably less than that of designing new tools.

A code in which the significance of the digits immediately reveals similarities, be they of materials, bought-out parts, components or tools, is of material assistance to other departments. Accurate descriptions and agreed alternatives and equivalents enable the Purchasing Department to consolidate requirements and obtain better prices through volume discounts and improved delivery arrangements. The estimating of the cost of new parts is facilitated, since the estimator has the means to make comparisons with the actual cost of similar parts designed in the past. The preparation of operation layouts and planning schedules is simplified by quick reference to those of similar parts and machine setting times are reduced by more economical planning and operation sequence.

Systematical Classification and Coding provides, therefore, a logical and sound foundation upon which to base a simplification programme which will ensure the economic planning and operation of the automatic factory. Variety can be reduced and, equally important, controlled. Each variety will normally require a minimum stock and, for every variety eliminated, there is no need to increase the holdings of the remainder proportionately. A more economic inventory can be established and maintained, fewer bins are required, storage space is saved, a tidier stores layout is achieved and the annual cost of holding stocks is reduced (see Fig. 6).

THE ANALYSIS OF MATERIAL COST OF A WORKS ORDER

Material Cost of Works Order

Code No.	*Old No.*	*Cost* s.	d.
1134-113	M2905L	2	0
1124-160	M2905L	6	6
1124-278	M1108L	6	0
1134-162	M1109L	8	4
1325-124	M1103L	9	9
1355-180	BB807L	10	6
1124-204	M2615L	11	0
1335-309	M2421L	5	8
1375-207	M6882L	10	6
1124-147	BB806L	10	0
1154-171	M57070		1
1366-131	M57070		3
1335-311	M2438L	10	0
1335-304	M24360		2
1134-109	M1364L	2	11
1355-303	M1364L	3	0
1134-113	M2119L	10	10
1154-140	M1110L	12	0
1154-180	N2905L	2	0
	Total cost	£6	1 6

Cost of Copper Alloys in Same Works Order

1325-124	M1103L	9	9
1355-180	BB8071	10	6
1335-309	M2421L	5	8
1375-207	M6882L	10	6
1366-131	M57070		3
1335-311	M2438L	10	0
1335-304	M24360		2
1355-303	M1364L	3	0
	Copper cost	£2	9 10

Fig. 7. During a period of rising copper prices, a company wished to establish the effects of this rise in materials purchased. The upper tabulation indicates the total material cost of a typical works order and the lower tabulation the copper cost, quickly obtained by extracting all items containing the digit " 3 " (copper and copper alloy) in the second position of the Brisch code shown in the first column of the tabulation. Further quick analyses can be made to establish the cost of bar, sheet, plate or tube.

Comparatively little thought has been given to the very important expenditure of storage costs. Many firms are of the opinion that it costs them per year no more than 10% - 12% of the relevant stock value. Some quote a much lower figure. An analysis of actual costs based on information obtained from a number of firms in this country has shown that this annual cost is, on the average, 20% - 25% of the stock value. This figure takes into account the cost of capital investment, insurance, accommodation, handling and maintenance, clerical procedures of purchasing, storekeeping and stock control, and the inevitable losses arising from deterioration and obsolescence. It is, therefore, somewhat alarming to find that an inventory valued at, say, one million pounds, costs, on average the fabulous sum of £200,000 per year to maintain.

If items are stored in code order, the location of each item is greatly facilitated, since, in addition to identifying and describing each item, the code numbers can be, at the same time, location (bin) numbers in stores, and cross reference files or separate bin numbers are eliminated. Where mechanised stores accounting on punched cards or electronic computers is in operation, or to be installed, much card space may be saved, sorting time reduced and greater information obtained from analyses and tabulations (see Fig. 7).

Time required to take stock is reduced since much preparatory work can be carried out beforehand, and time hitherto spent in identification due to misleading and ambiguous descriptions is saved.

The technical skill and experience of designers are not curbed in any way and the introduction of new materials is not prohibited providing that they can be fully justified on grounds of, say, technical improvement, better machinability or cost reduction. Design developments and engineering changes which are fully justified follow the normal course but the code, which provides the means quickly to locate *all* existing similar drawings, prevents unnecessary parts being designed and ensures that only essential new ones are created.

When a demand cannot be satisfied from stock, similar items in stock can be quickly traced and the most suitable items selected, modified if necessary, and offered in lieu. Small manufacturing batches or frequent machine settings are avoided and the range of spares held can be reduced, since the same requirements can be satisfied from a smaller variety of stock, particularly when items are stored in the part-finished state, the finishing operations being carried out to satisfy each specific demand.

The progress made in production techniques and manufacturing processes during the first half of this century has created problems of increasing complexity which industrial management has had to face, and among these is the vital one of keener foreign competition, particularly in recent years. In a world market which is steadily expanding — even now only one half of the population of the world makes any demand on the products of industry — lower selling prices and prompt delivery times will be undoubtedly two of the strongest weapons which we shall have to forge to combat this competition.

Industrial automation offers this country its greatest opportunity to make production economies and to reduce manufacturing costs, but it will demand a high degree of specialisation both in men and

machines and considerable rationalisation of product design.

Unnecessary variety must be rigidly dispensed with and products must be designed and produced from a minimum variety of materials and parts, with the aid of the minimum variety of tools, while at the same time improving customer appeal. The need to simplify is inescapable.

Below are case studies of variety reduction achieved by types of materials and by types of industry, together with some financial and other benefits obtained as a result of applying the "Brisch" principles of Classification and Coding.

SOME EXAMPLES OF ECONOMIES AND BENEFITS ACHIEVED

(a) One firm of over 4,000 employees manufacturing machine tools and heavy vehicles had this method applied to their primary materials, bought-out commodities and component parts, as a result of which their own accountants state that a saving of £45,000 was obtained in the first year.

(b) Reductions of up to 10% in the numbers of drawings produced have been achieved and in the case of one firm resulted in savings amounting to £10,000 per annum in the Drawing Office alone.

(c) Another firm held 15,000 tools of which 10% were found to be no longer in use. With the help of the Code they were brought back into use again to make new components at a modification cost of one-third of the cost of producing new tools.

(d) The delivery of 12 machines, costing £10,000 each, was in danger of being held up due to the faulty processing of one component. No spares or raw material were available but the Code revealed that components belonging to an entirely different machine and of the right material existed, and these, after simple modification, were substituted for the rejected parts. An otherwise inevitable and appreciable delay was avoided and delivery made on time.

(e) The time required to take the inventory at an electrical firm was three to four weeks. After classification and coding by the " Brisch " method, this was reduced to two or three days.

(f) Classification of packaging cartons revealed that in one instance an expensive material, namely, boxmaker's linen, was being used. As a result, a cheaper material, which passed all the tests to which the linen had been subjected, was substituted. A saving in material cost of £8,000 per annum was obtained.

(g) One firm writes : " It did an otherwise impossible task recently when we decided to broach all keyways instead of slotting, by sorting out in a couple of days all the different combinations of key size, bore size, length and material ; apart from this its use in new design is continually increasing."

(Further examples of variety reduction are illustrated on the following pages.)

EXAMPLES OF VARIETY REDUCTION OF PRIMARY MATERIALS IN VARIOUS INDUSTRIES

Type of Organisation or Product	No. of items handled, i.e., before classification and coding	After Classification and Coding				
		1st reduction after identification by eliminating duplicate and obsolete items		2nd reduction by deliberate elimination of unnecessary items, i.e., Simplification		Total overall reduction
		No.	%	No.	%	%
Elec. and Mech. Railways Equipment	9139	2423	26.5	1607	17.6	44.1
Switchgear and Elec. Equipment	4106	639	15.6	473	11.5	27.1
Elec. Accessories and Equipment	3487	293	8.4	983	28.2	36.6
Railways	3095	60	1.9	724	23.4	25.3
Aircraft Equipment	3039	964	31.7	1125	37.1	68.8
Refrig. Machinery, Lifts and Escalators	2729	665	24.4	135	5.0	29.4
Elec. and General Engineers	2572	65	2.5	1118	43.5	46.0
Transformers and Switchgear	1931	334	17.3	304	15.7	33.0
Diesel Engines	1745	155	8.9	733	42.1	51.0
Diesel Engines	1280	208	16.3	382	29.9	46.2
Office and Stores Equipment	1244	164	13.2	280	22.5	35.7
Cranes and Excavators ...	1072	68	6.3	205	19.1	25.4
Sandblast Equipment ...	868	37	4.3	123	14.2	18.5
Motor Vehicles	746	93	12.5	274	36.8	49.3
Locks and Security Equipment	580	32	5.5	336	58.0	63.5
Turbines and Pumps ...	579	24	4.2	187	32.3	36.5
						Average Reduction 39.8%

EXAMPLES OF VARIETY REDUCTION OF FIXINGS AND FASTENINGS IN VARIOUS INDUSTRIES

Type of Organisation or Product	No. of items handled, i.e., before classification and coding	After Classification and Coding				
		1st reduction after identification by eliminating duplicate and obsolete items		2nd reduction by deliberate elimination of unnecessary items, i.e., Simplification		Total overall reduction
		No.	%	No.	%	%
Elec. and Mec. Railway Equipment	3927	637	16.2	1504	38.3	54.5
Electrical Equipment ...	3399	350	10.3	553	16.3	26.6
Photographic Equipment ...	3328	83	2.5	549	16.5	19.0
Steelfounders Cranes and Equipment	2710	410	15.1	449	16.6	31.7
Transformers and Switchgear	780	150	19.3	84	10.8	30.1
						Average Reduction 33.7%

EXAMPLES OF VARIETY REDUCTION OF COMMODITIES OTHER THAN FIXINGS AND FASTENINGS IN VARIOUS INDUSTRIES

Type of Organisation or Product	No. of items handled, i.e., before classification and coding	After Classification and Coding				
		1st reduction after identification by eliminating duplicate and obsolete items		2nd reduction by deliberate elimination of unnecessary items, i.e., Simplification		Total overall reduction
		No.	%	No.	%	%
Food Processing Machinery...	7812	1036	13.3	628	8.1	21.4
Photographic Equipment ...	5076	481	9.5	507	10.0	19.5
Steelfounders, Cranes and Excavators	1339	364	27.2	259	19.3	46.5
Transformers and Switchgear	971	182	18.8	Action not yet taken		18.8
					Average Reduction	22.7%

"SCHEDULING FOR BATCH PRODUCTION" — concluded from page 570

Expression (11) is a good approximation, provided q is not too small. For cases where the constant cost content is low (i.e., u is small), the approximation can be modified by subsequent use of (10).

Scheduling n products.

When n products are included in a production cycle, it is possible to ensure that each product will always be in stock when the consumption times for all products are the same :

$$T_{c1} = T_{c2} = \cdots = T_{cn}$$

The functions $\frac{\text{profit}}{\text{investment}}$, profit and rate of return can be expressed in terms of the lot-size for product 1 and when these functions are maximised the appropriate lot-size for product 1 can be found.

Maximum $\frac{\text{profit}}{\text{investment}}$ occurs when

$$Q_1 = \sqrt{\frac{\Sigma s}{\Sigma \alpha^2 K}} = \sqrt{\frac{s_1 + s_2 + \cdots + s_n}{K_1 + \alpha_2^2 K_2 + \cdots + \alpha_n^2 K_n}}$$

or $Q_1 = g_1 Q_{1m}$ (12)

where $g_1 = \sqrt{\frac{\Sigma s / s_1}{\Sigma \alpha^2 K / K_1}}$

and $Q_2 = \alpha_2 Q_1$; $Q_3 = \alpha_3 Q_1$; $\cdots$; $Q_n = \alpha_n Q_1$

Solutions for maximum profit and maximum rate of return can be similarly obtained, although the one for maximum rate of return is somewhat complex and not exactly convenient for practical calculations.

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MASTER AND MAN—

A New Look at an Age-Old Relationship

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Mr. Gordon England is an example of an adventurous Englishman whose life story reads almost like a novel. Engineering, flying, motor-racing, yachting, ski-ing and farming are just a few of the many interests which he has wholeheartedly embraced during his career.

He is first and foremost an engineer, and was trained at the Great Northern Railway Works, Doncaster. In 1909, *he turned his attention to what was then the new science of aeronautics, and became an aircraft designer and test pilot. He holds Pilot's Certificate No.* 68. *The design and manufacture of aircraft claimed his attention throughout the First World War, but in* 1919 *he entered the automobile industry, and became a successful racing motorist, subsequently designing the Gordon England motor-car body.*

In addition to his engineering activities, Mr. Gordon England has had extensive managerial experience, and has held a number of Managing Directorships. From 1931-1933, *he was a member of the Gorell Committee on Civil Aviation, and he is also a Past Chairman of the Engineering Industries Association.*

He has been a member of the Institution of Production Engineers for over 30 *years, playing a very active part in its development, and he is widely known throughout the membership for the many interesting and sometimes highly provocative Papers he has presented to the various Sections.*

THE purpose of this Conference is preparation for "the things to come" and its theme is that the substantial technological changes ahead will have far-reaching industrial consequences here and abroad.

The rate and volume of change which any society can assimilate is, in the final analysis, wholly dependent upon the attitude of mind of Society's individual numbers.

History contains many illustrations of decline and disappearance of Societies, apparently because of inflexibility of the attitudes of mind in their peoples and consequently their inability to assimilate change.

Herald of change

The Institution of Production Engineers appears once again in the role of herald of change. On this occasion it has summoned us to attend a sumptuous banquet of technological fare; of a fresh and most varied kind. Our ability to assimilate this rich repast depends upon our attitude of mind. The security and future prosperity of our society will depend very largely upon the ability with which members of the Institution "manage" these changes into being with the willing acceptance of "the managed".

Meaning of "Master and Man"

The term "Master and Man" is of great antiquity and it is significant that it still has meaning and relevance. This term, when used, still causes emotional reaction of the most varied kind. On the other hand, the term "Master and Man" connotes, to many involved with the exercise of management, the same thing as the term, "Management and Managed". There is widespread confusion over the meaning of this term because of the vast variety of definitions which different people attach to it. It is the object of this Paper to make some contribution to the exclusion of the use of this term so far as industry is

concerned. Its use should be considered no more appropriate in the social structure of industry than would be an endeavour to retain, in some way, the term "bows and arrows" in connection with nuclear bombs, on the plea that both are descriptions of weapons.

The Employers and the Trade Unions

The phrase, "Master and Man", was deliberately chosen by those who were responsible for setting the programme of Papers, to designate the relationship of Employers' Organisations and Trade Unions.

In this Discussion Paper, it is beyond practicability to attempt to make a detailed and reasoned examination of the history of the ever changing relationship of "Master and Man" over many decades. The phrase, "Master and Man", has come a very long way in history and its definitions and connotations have varied with ever changing environment and circumstances. For the purpose of this Paper, the enquiry is restricted to the industrial era and particularly the period since the foundation and growth in power and organisation of both Employer and Trade Union organisations.

Each of these "power" groupings has consciously and even more unconsciously been greatly influenced in their thought, behaviour and organisation in the relationship of Master and Man by traditions to which they have been heirs.

Still steeped in attitudes of mind, the product of many generations of slavery, serfdom and other forms of "Tied Man", at the dawn of the industrial era the "Master" regarded "Man" as a valuable form of industrial material to be used or discarded as seemed expedient. It was not considered the "Master's" responsibility to be concerned with protection and development of the *whole* "Man". The "Master" was directly concerned in using the necessary human material conveniently called "Man", and which was readily available, for his commercial and industrial processes, with the same skill and frugality that he bestowed upon the use of his buildings, processes, machines and inanimate materials. His duty, as he saw it, was to buy in the cheapest market for all his requirements. He regarded his industrial activities as highly specialised functions which were not to be confused with his broader duties to Society, and of which he was only dimly aware when judged by our present-day concepts.

No part of immutable law

Because the phrase, "Master and Man", has come so far in history we are apt to accept without question the widely held belief that it expresses some aspect of immutable law. What justification is there for this assumption?

It will be shown later in this Paper that throughout the ages Man has striven to displace or replace the Master. Most people will readily recall that recent outburst of an exultant politician: "We are the masters now". The significance of this statement rests in the fact that for many years his Party's theme had been the innate iniquity of the Master and Man relationship. The word, "Master", indicates variously a governor, a commander, an owner or a teacher, and this elastic definition can be made to serve all points of view.

Historically, Man in his relationship to the Master has been defined as a slave, a serf, or the many forms of the "tied hand". In this connection, we are apt to forget how recent have been the passing of slavery and serfdom in what today is termed the Western world.

It is therefore not surprising or unreasonable that some of the traditional attitudes of mind inherited from these bygone days persist, albeit unconsciously, even until today.

There are still substantial numbers of people in society who suspect no incongruity in many of our current interpretations of this "age-old relationship".

A universal relationship

There is a relationship which today is almost universal and in which most people are involved to some extent or another. It is that of those who "manage" to those who are "managed". It has grown out of the age-old relationship of "Master and Man" and it is greatly bedevilled by its inheritance of traditions and many of its evil features.

It is the purpose of this Paper to make some positive attempt to disentangle the good and bad traditions and practices and study the relationship, its growth and changes, without bias, self-interest or emotion, while doing full justice to the good which, in fact, is our civilisation today. There is little more difficult to achieve but at the same time so stimulating, worthwhile and satisfying. Difficult, because we are inevitably, unconsciously conditioned by our traditions, environment, emotions, attitudes of mind and vested interests. Stimulating, because in undertaking this exercise we are participating in creative activity. Worthwhile, because whether we have hitherto been conscious of the fact that the human factor is dominant in every situation or not, we shall now come to recognise it. Satisfying, because, as in the course of our researches we discard the outworn shibboleths and clichés of yesterday, we shall discover that "the things that endure" begin to stand out more clearly and become more secure in our minds. We shall begin to enjoy a sense of relief as we feel the accumulated load of expediency which has weighed us down, almost to the point of despair, slipping from our shoulders.

Taking a new look

If we are to be successful in taking "a new look at an age-old relationship" we should start by clearing away some of those things that have grown up in the foreground of Society's great affairs and which so greatly obscure our opportunity and ability to look upon the scene from new angles.

In our study of the environment within which industry is conducted at present, we may not enjoy what we discover as it is generally distasteful to be confronted, suddenly, by the uncomfortable thoughts and impressions of others. But we should decide that the arbiter in our studies is the pursuit of truth, not the protection of mental comfort.

Most of us at this Conference are technologists concerned with the duty of injecting worthwhile technological advances of one sort and another into commerce and industry. We know that perhaps the most unstable and evanescent thing in our experience is technology, yet we seem, from observation, to resist change in this matter with an obstinacy comparable to that of those whose walks of life sometimes impinge on ours but seem otherwise remote and even backwards. We are at heart all of a similar attitude of mind, and thus it ill behoves us to be arrogant in our criticism of others.

Vulnerability of criticism

So vulnerable to criticism have most of our organisations become, be they concerned with Government, Parliament, politics, religion, commerce or industry, and, indeed, the learned and professional bodies which abound here and in countries elsewhere, that there has been developing an almost universal defence mechanism or cult which seeks to suggest that criticism is improper and a regrettable lapse from decent behaviour and that it must be, always, ill-intentioned, disloyal, anti-social—indeed, an evil thing. Criticism is an essential factor where progress is desired. Lack of criticism ensures rapid decline and dissolution. The reason is not far to seek, for by the nature of things all human organisations are fallible and with the efflux of time need constant readjustment if they are to keep on course. One cannot begin to take a "new look" at anything without adopting a critical attitude, and this fact does not justify the assumption of those who seek refuge from criticism, that the criticisms are motivated by evil, unmindful of the public good that the criticised has achieved or that the critic is demonstrably unsympathetic to, and lacking in, understanding of the notable and commendable endeavours of those who have brought about the personal and public social benefits which our age enjoys.

Past achievements and errors

Our past achievements, *on the right side*, in all walks of life are vast and splendid, and for the purpose of this Paper are assumed to be agreed. It is the business of this Paper to focus attention upon the canker of errors which has grown up alongside the achievements. Because of familiarity with this canker it appears to be widely believed to be an integral part of the good, whereas this Paper seeks to show that these errors have no validity and should be discarded as outworn instruments of an age of uninformed expediency.

There is no principle or permanence behind them: they are the outcome of our shifts in meeting transitory circumstances.

An exciting period ahead

There seems ample evidence for claiming that we live in one of the most exciting and potentially productive periods in history.

Through the advance of physical science, humanity today stands on the threshold of the physics of the primary state of matter. In doing so science has brought mankind, in the last 50 years, to the position where almost every aspect of human society has lost any semblance of stability. The technological developments which have emerged from the application of scientific discovery are immense, both in diversity and importance. There has been failure to ensure that there was comparable knowledge of the effects of all this material progress upon mankind. We should study the environment of our time with some attention and be prepared to consider dispassionately, with objectivity and quite impersonally just what are the ecological implications of these technological developments.

No exact knowledge exists on the incidence of these great technological developments that have become during the past 50 years an integral part of the environment, in varying degrees, of people all over the world. The impacts of such developments as electronics, the internal combustion engine, the aeroplane, new raw materials and processes, and the extension, almost to the state of universality, of such means of communication as radio and television, upon the attitude of mind of great groups of people, is very little known and understood. All that we seem to be aware of is that there appear to be great unsettling forces at work which are affecting our traditional forms of social behaviour far beyond our understanding—social behaviour which has perhaps hitherto endured for countless ages, because it was the best mankind could devise to suit the apparently stable environment. Suddenly, all our cherished social patterns and hitherto accepted forms of behaviour seem to be made invalid by fundamental environmental changes, thus leaving mankind bewildered and frequently much afraid.

Lack of balance

It seems to be an historical fact that most previous Societies have consistently suffered from a lack of essential balance and a consequent instability which, in the long run, has brought about ultimate downfall. What is here designated as essential balance can be defined as the conscious effort, by any Society, to ensure that in all things its members lead lives which give proper scope for the orderly exercise of all man's natural endowments.

The whole man

The cult of the "whole" or balanced man has been a theme beloved by philosophers and saints throughout history. They have stressed the social dangers arising from unbalanced or specialised man, but their theme has found little favour and support from the organised society of their time. The age we live in may be as much out of balance as any previous age because of its economic and technological specialisations, and this may well be the explanation of a seeming state of greater instability than in that of any past society.

Continuing imbalance

It is significant that the two World Wars which have occurred in our generation, and which can fairly be claimed to have made grave contributions to social imbalance, could not have been waged except for the technological developments of our time in the fields of commerce and industry. Mankind is now con-

sideting, wirh growing alarm, the possibility of the advent of a third World War which many informed people believe, if it comes, must be catastrophic to Society because of the use of the technological developments with which it would be waged.

Fortunately one of the historical consequences of a state of imbalance in Society seems to persist in our age, too. Forces appear to emerge which cause the mass of mankind to make great but apparently unconscious efforts to create conditions which, in the long run, restore balance and make for stability.

These unreasoned but intuitive movements, often apparently illogical and chaotic in their manifestations, are usually dismissed as just further examples of the waywardness and unpredictability of "human nature"—a phrase on almost everyone's lips, and meaningless because of its almost unlimited interpretations.

Lack of knowledge of mankind

Our knowledge of man is remarkable for its deficiencies which far exceed our mite of understanding.

When we propose to make use of some new material, machine or process, or apply existing ones to new ends and in new conditions, we make a close study of their characteristics, limitations and environmental reactions in operation. We consider it no less than foolish to ignore making this study.

In the case of the management of men, we adopt no such rational approach. We assume that this factor, MAN—the dominant factor in every phase of the cycle of production—is thoroughly understood so far as reactions to almost every conceivable, known or unknown, situation is concerned. We assume we may safely rely upon Man's well-reputed capacity for almost infinite adjustment to provide against any eventuality or shortcoming in Management.

Most of what passes for knowledge is the result of trial and error and experimental research, mostly conducted in environments which do not apply or have ceased to exist. The result of applying what has been observed in one environment to radically different ones has frequently been unsatisfactory in the result. This may be the cause of what seems to be an attitude of indifference on the part of so many of those in authority to the problem of understanding the nature of Man, and the reason for so much dogma in practice in the so-called scientific management of men, in the "Master and Man" relationship and which is demonstrably consistently in error.

Man's enduring characteristic

There is one enduring characteristic of Man which physical science has established. No two specimens of the species are identical in any physical respect. It is known that the law that governs the fact that no two individuals have identical finger-prints applies with equal precision to all other items of their physical structure. Thus it seems that we are confronted with an immutable Law, the Law of Infinite Variety—an infinite variety of classification and variety within any given classification. In the inorganic field the snowflake is perhaps the most fascinating example of the operation of this law.

So far as the evidence goes, it seems to confirm a similar operation of this law in the fields of mind and spirit.

Man's dominant motive

All observation supports the conclusion that the dominant motive in Man is the creative motive, and that this motive finds expression and satisfaction in countless ways.

Economic Man

Man's outstanding economic feature is that from the instant of conception to the moment of dissolution, Man is continuously a consumer in an almost infinite variety of ways, whereas he is a producer in narrow specialisations during a minor fraction of life's span, at the best. His activities as a producer are subject to frequent interruptions.

Influence of environment

There is growing reason to suppose that, in common with other organic bodies, physical Man is influenced by the environmental seasonal changes of the year to quite an unexpected degree. Later in this Paper this and other criteria will be the basis for an examination of the relationship of Master and Man and Management and the Managed, but, meanwhile, there are some other matters to be brought into focus.

Organisations are inert

From time immemorial Man's concept for the achievement of progress has been through the creation of organisations and the exercise of power over other men which the existence of organisations enables him to evoke. By establishing a leader, forming a combination of people, allocating functions and duties, the use of a variety of skills, Man has achieved results which so far cannot be readily matched by a group of individuals working separately.

No organisation of itself is capable of creative action; that function remains always the unchallengeable domain of the individuals of whom it is comprised. The function of an organisation is to act as an instrument with which power is evoked to carry out the creative activities of Man. It would be difficult to find many organisations where those in authority do not seek the extension of their power and authority over other men in the furtherance of the organisation's vested interests.

Leadership and power

Thus was the concept of leadership brought into being and the relationship of Master and Man established. The attributes desirable in the leader have constantly varied with the changes in social objective and in environment. But as the Master of every organisation sooner or later becomes more deeply concerned with the preservation of power evoked by the organisation than with the original creative objective for which the organisation was formed, this creative objective tends to recede into the background. With the efflux of time, more and more does the emphasis on expediency, and reliance on shibboleths and clichés take precedence over creative objective.

If, meanwhile, the leader has acquired sufficient power and authority he frequently exercises these

ruthlessly and unashamedly to cover up the lack of a sound creative policy. History contains a vast number of illustrations of reliance upon authority and power being substituted for creative policy, resulting in the leaders resisting change, with the inevitable ultimate result that the pressure of events becomes irresistible and the leader, his authority and power, and frequently all his creative and positive accomplishments, too, are swept away. This is still happening all around today.

Dogmas, shibboleths and rituals

Any close study of the many organisations in commerce and industry or connected with these activities will uncover the fact that they are riddled with dogmas, rituals and shibboleths. The prevailing belief so widely held that rigidity of outlook and the unbending adherence to effete dogmas, rituals, shibboleths and the worship of authority are peculiar to religious bodies appear to have, in this matter, arisen from the fact that they have provided a pattern of behaviour that has endured for thousands of years, but which almost all other organisations have since adopted as their own—albeit unconsciously.

A consistent pattern

It has already been observed that no two men are identical and that no organisation has creative capacity. The fabric of history shows that in its weaving the pattern of behaviour remains consistently that of a never-ending conflict between the leader's pursuit of power over other men's bodies and minds in order to protect the position of leadership, and the cumulative pressure from those dominated to assert their innate individuality and their desire to enjoy the opportunity of giving rein to their creative motive. It is when there are substantial changes in environment that this pressure seems so frequently to reach its climax and the situation becomes unendurable. Time and time again, this conflict has ended catastrophically and frequently all that may have been beneficial in the situation is swept away with what was admittedly evil.

Inevitably Man, sooner rather than later, driven by his dominant motive, the creative motive, has started to rebuild and in his impatience for progress set up new organisations on the old familiar pattern of "Master and Man" with all its implications. In due course the whole sorry business has been repeated and the pattern reproduced once more, usually in its entirety.

The purpose of industry

Adam Smith, the author of the famous dictum that "Consumption is the sole end and purpose of all production", saw the purpose of industry with the clearest of visions.

There never has been a more compact or less vulnerable statement of what should be the purpose of industry. Tested by this dictum so much of our present policies and practices in commerce and industry appear to ignore Adam Smith's dictum, no doubt quite unconsciously, and yet people wonder at the problems which beset us.

If commerce and industry fail to serve this grand purpose, doom is inevitable. The harsh exactness of Adam Smith's dictum has probably made it unpopular as arbiter of the policies of our industrial organisations, be they Employers' or Trade Union. Yardsticks less precise and more complex in character and manipulation seem to be more fashionable, and esteemed as better suited to a period in history dominated by expediency and double-talk wherever the avowed practice does not measure up to the dictates of principles.

It is perhaps useful to reflect that only so recently as when the late, and rightly famous, Henry Ford announced his intention to design and manufacture automobiles suitable for the use of those employed in making them, and at prices they could afford to pay, the announcement was the subject of almost universal derision, although this may seem unbelievable to some today. Yet Henry Ford's policy was in line with Adam Smith's dictum.

It has been stated that all men at all times without interruption are consumers, and it follows that although the people in commerce and industry form a substantial part of the whole body of consumers, they cannot take out as much as they put in without damage to that greater part, the whole of Society and with ultimate ruin to themselves.

The conflict for power

We perhaps begin to appreciate, even if but dimly, from this examination of the known facts that the power politics of the "Master and Man" relationship have no valid position in a situation in which clearly there should not be *two sides*. We are beset today by a multitude of power groups bent on improving their organisational position in order that they may evoke still greater power. The serving of the purpose of industry has little real place in their present policies and their resistance to change in the right direction hardens as the pressure of events rises. Tensions are being set up and are growing alarmingly, and there are the usual signs of actual conflict breaking out between these groups, in the foreseeable future.

Industrial discontent

Industrial discontent is widespread and growing as a result, perhaps, as much as anything, of these signs of senseless and futile major conflicts between the Employers' Federations and the Trade Unions, which is being felt by the great body of people in industry as a growing evil which they are powerless to control. It is significant that there has had to be intervention by the Government-appointed Courts of Inquiry into the disputes in the shipbuilding and engineering industries. The reports disclose no point which could not have been resolved by men of goodwill, free from the thraldom of the "Master and Man" power complexes to which reference has already been made.

However much it may be denied, there is no evidence which does not show that the leaders on both sides of these disputes were dominated by the "power" of the organisations they are supposed to control. It is one of the fallacies of our time that men in their individual capacities can, for the reason

already advanced, substitute principle or power in almost any modern organisation, be it political, industrial, commercial or professional.

The great mass of the people engaged in industry the world over are uneasy and feel helpless at the trend of industrial events; lacking the facts and understanding, they are forced back on to their emotional background. The outcome of this is a situation in which the vain attempts of the "Master" or "Man" groups to cope with the rising discontent produces the most unsatisfactory and seemingly illogical results. Meanwhile, the tide of discontent rises and invades channels and backwaters hitherto free from its influences. We seem unable to envisage the possibility that the growth in power of our "Master" or "Man" organisations may be a symptom of the existence of a disease too deep seated to respond to the conflicting cures these very organisations so confidently recommend. Are we not faced with evidence of man's unwilling and ineffectual efforts to research into causation, and have we not clear evidence of his devotion to the efficacy of remedial measures? There are an increasing number of observant and informed people who believe that research into causation would reveal some surprising information on the relative importance of the factors which go to make up the sum of what is known as "industrial discontent". Here is what should be the real job of the "authoritative and impartial body" recommended by the Courts of Inquiry in their report published at the beginning of May this year.

Standard of living

Both "Master" and "Man" organisations join with Parliamentary and Government agencies in having much to say on the "standard of living". From their various pronouncements, it seems fair to conclude that each organisation has its own definition of what should be envisaged. The organisations most vocal in demanding progress in the direction of a higher standard of living seem to be advocating the most restrictive and specialised interpretations of what is desirable. They give the onlooker little confidence that they have any clear idea of just what should be embraced in the term "standard of living". Their utterances give little indication that the course they so fervently advocate as the right one to reach the higher standard, would seem to aggravate Man's present state of imbalance and contribute nothing to the achievement of that desirable state of being the era of the "whole man".

What of the Master and Man?

It will be convenient at this stage of our taking "a new look at an age-old relationship", and using the criteria that have already been outlined in this Paper, to examine in some detail what appear to be the incongruities attributable to the "Master" as an individual and also as representative of the "Master" organisations. It will be profitable to observe what effect the "Master's" changing interpretations of what should constitute the proper order of the relationship between "Master" and "Man", has had upon "Man". We can at the same time observe how the application of this unstable interpretation has been offset by the reactions of Man.

The right to leadership

1. The "Master" assumed that there were inherent rights of leadership and the use of "power" for enforcing compliance. Various manifestations of "power" were involved, e.g., the power to hire and fire, the power to fix pay, the hours of work, etc. "Man" reacted by combinations against these enforced conditions and with the intention and expectation of establishing a balance of power. This is most admirably stated in the words of Mr. E. Fletcher, Secretary of the Production Department of the Trades Union Congress: "The job of a Trade Union is to extract from reluctant employers higher rates of pay, including adequate overtime rates, as well as associated benefits, such as reducing, when appropriate, the hours of work, producing a reasonable weekly wage, and increasing holidays with pay."

2. The "Master" thus established, in fact, the concept of the "two sides of industry", a concept to which "Man" has responded with enthusiasm, and both have fostered the belief that it is a matter of principle in our modern society, apparently quite unaware that such a concept serves only to cover up the inherent errors in the situation.

Again, to quote Mr. Fletcher: "Every democratic society must have its own good healthy strong Trade Unions capable of putting forward the views of its members, discussing and reaching agreement; capable also of exerting pressure when necessary on a wide range of industrial matters."

He adds, with every justification so far as can be judged by the pronouncements of the Employers' Organisations, that "This is appreciated by most employers, but not all."

The reluctant "Master"

3. The "Master" has throughout the industrial era been unwilling to take a lead in improving the "Master" and "Man" relationship with the change in environmental conditions. He has been unable to see that the implications of Adam Smith's dictum are that the relationship should be fundamentally one of partnership, and that in the long run the "Master's" best interests would be safeguarded by safeguarding and advancing the interests of "Man".

"Man" has reacted to this reluctance by extending his powers to cover a wide range of matters affecting industry. Today the Trade Unions claim, with considerable justification, that they exert a positive force in assisting the development of industry because they clearly envisage the outstanding importance of increasing national output. They claim the initiative in developing "full employment". In fact, the Trade Unions claim that the initiative in all matters of relationship has largely passed from "Master" to "Man" through the effective exercise of the latter's ever-growing power.

As a suitable commentary on this situation, some remarks made so recently as 3rd May by a prominent industrialist could hardly be bettered. Speaking in Perth at a conference organised by the British Institute

of Management, Mr. H. P. Barker, Chairman of Parkinson & Cowan Limited, said: "Top management had not yet understood its (full empoyment) significance. When men and women had a choice about where they worked, top management had to create working environments in which they would want to participate. If any management failed in that, its long-term extinction was 'pretty likely'." (*The Times*, 4.5.57.)

Dual control

4. The "Master" because of the lack of initiative is responsible for bringing into existence a system of dual control. He now reluctantly shares leadership with "Man", while disputing its reality. The "Master", still preserving the theme of the "two-sides" of industry, denies the reality of this dual control, with the result that those responsible for carrying out this dual leadership having divergent objectives in many cases, and in many more cases, great differences in matters of approach to the objectives even where the objective may be a common one appear to be in a state of confusion.

Is it, therefore, surprising that the relationship of "Master and Man" has recently been stressed to a degree beyond endurance?

The Courts of Inquiry set up by the Government recognise that this situation is a complex one, and suggest the setting up of an authoritative and impartial body to consider the wider problems involved in the conduct of industry.

Unhappiness in industry

Here with advantage Mr. H. P. Barker can again be quoted: "Many people who worked in industry were very unhappy and expressed their unhappiness in many ways harmful to themselves and to their employers. Much absenteeism was due to neurotic behaviour, and both men and women had demonstrated clearly that they could not be bribed into contentment by high wages or by new canteens."

He went on to say that he had nothing but contempt for the way that problems of human happiness in industry were often treated under the now disparaged title of "welfare". "Workers wanted security in human relations, and top management must evolve techniques which recognise the existence of social groups in an establishment and work to preserve them as far as possible." (*The Times*, 4.5.57.)

A way out?

Before leaving this part of the enquiry in the chaotic situation which it is claimed has been fairly disclosed by the preceding part of this Paper, it is appropriate to quote the concluding paragraph of the leading editorial from *The Times*, 3rd May, 1957:

"The Courts suggest that it should be a small body (the authoritative and independent body) with which the Treasury should be associated, but it is obvious that it would have to be demonstrably independent of the Government if its pronouncements were not to be regarded with suspicion. It is also suggested that the British Employers' Confederation, the T.U.C. and the nationalised industries should be associated with it; but no body which depended upon the agreement of these various parties would be likely to prove very useful. To achieve its objects it would have to be a small and independent group of men, probably with their own staff, whose experience and aptitudes would enable them to examine and present facts without political bias and without respect for conventional attitudes. Given the right men something substantial might be accomplished."

A statement of the situation upon which many must surely agree it would be difficult to improve.

Unwelcome to present order

There is no reason to charge the British Employers Confederation, the T.U.C., the Treasury, Government or Parliament with, variously, bad faith, lack of sincerity or of having evil intent, any more than one is justified in bringing these charges against those who in the past have been convinced that the world was flat or that the sun went round the earth. Their beliefs and attitudes of mind are conditioned by what they envisage.

The power groups in Society must quite justifiably, for the reasons already advanced, regard such a "small and independent group" as is proposed by *The Times* leader writer with disfavour, because it would be outside the established order of the distribution of power. All power groups are jealous of their positions and are satisfied that their forms of organisation are endowed with some of the essence of the permanent.

Failure of "Master"

It is submitted at this point in this Paper that it is demonstrable, by what has emerged, that the "Master and Man" relationship has failed to withstand this critical "new look".

The relationship is undoubtedly age-old and may have been best suited to environmental conditions which no longer exist, but it is submitted that the "Master and Man" relationship can now, with advantage, be discarded. The complications in social structure which have resulted from attempting to retain some of the traditional aspects of that relationship which Society has been loth to discard are indeed formidable. Simplification of future industrial relationships is a problem before which the stoutest heart may quail, but somehow the position not only has to be resolved, but will be resolved by the force of events, even if we fail to evolve a positive solution to the problem by the exercise of creative thought.

A way of escape

There are reasonable historical grounds for suggesting that those great organisations, whose power now dominates our industrial society will, when faced with the inevitable crisis of a final clash of their forces if they pursue their present course (being devoid of creative ideas whereby the crisis might be avoided) cast about for some ready-made solution which will enable them to save face. Until the moment of crisis arrives, any ready-made solution, including the one they will finally espouse, will either find little favour with the powers-that-be, or, in all probability, will be

completely ignored. Then, like the maid in the poem who, "vowing she would ne'er consent, consented", they will clutch at some ready-made solution and accept the inevitable changes involved.

Service and power

The following ready-made solution is offered: that we adopt and practise a new concept of management: Management by Consent. Perhaps it will be useful to define what is understood by Management, for the purpose of this Paper. "Management" is the art and science of getting people to co-operate, willingly, in carrying out some joint activity to mutual benefit, with the least expenditure of human effort. Management by Consent is the way that definition may be given expression in fact.

If we are to succeed in the harmonious development of our Society (which, this Paper suggests, seems justified as an objective), those who hold the leadership in affairs or aspire to that leadership, cannot achieve it by power. They will have to accept an appropriate alternative, such as Management by Consent. This alternative involves the adoption of entirely new attitudes of mind towards what are the desirable industrial relationships between individuals in all positions and status. Indeed, for complete success and harmony these new attitudes of mind must spread to all other walks of life. These attitudes of mind involve, for example, the conscious recognition by all the individuals in an industrial group that the function of management is an attribute which is capable of being more highly developed in one particular individual than another, but that fact does not denote (in the manager) any intrinsic superiority as an individual, and that the proper exercise of the function of management can only result in benefit to the group involved. Indeed it is essential for the wellbeing of every individual in the group.

No supermen

Society has for too long been conditioned, by biased propaganda, into believing that there are such individuals as "supermen", and that these, by virtue of the "fact", are to be found in leadership. This belief is wholly erroneous in all walks of life. In commerce and industry, as in other fields, there are exceptional managers, good managers, managers and indifferent managers. Managers are as varied in their ability, characteristics and performance as are singers in their field of activity. The present existence of the factor of power results in some distortion in grading of managers; occasionally, but fortunately, right classification and right judgment seem to be the rule. The exception is therefore "news" and, because of publicity, distorts and unbalances public appreciation of the overall managerial position. There seems no valid reason to suppose that the managers, who owe loyalty to the power organisations who employ them, would be unable to adjust their behaviour rapidly to the requirements of Management by Consent, providing they feel assured of the goodwill of their power group.

A useful illustration

The following illustration is perhaps appropriate to a proper appreciation of the character of Management by Consent. A talented singer has no power over an audience except the inherent emotional and spiritual powers associated with the presentation of the art. What the singer offers as a service to Society are the qualities and benefits which the exercise of artistry invokes in those who enjoy this service to Society, and of the benefits in which the singer, too, is involved. The singer, exercising this creative art, is rewarded by the patronage of Society for just so long as the artist can give satisfactory service. Both the singer and Society are well aware of this relationship and that with the efflux of time new, and perhaps greater, singers will emerge and must, in due course, supersede the present artist.

When that time comes nothing can long delay its inevitable consequences. In most cases these transpire without causing a ripple on the social surface. The singer has lost no caste as an individual and is, in all probability, regarded with lasting affection by Society for the past benefits it has enjoyed from the singer. It is not true that at any time the singer had any material power over the lives of the public served; nothing beyond the ability to serve others and brighten their lives. Such artists may have served, in many cases, people of great prominence in other walks of life, and who, in their turn, have given or are giving great public service, and also reaping great rewards. Yet the only power these people possessed over the artist was the power at any time to withdraw their individual patronage. So it should be with the manager exercising his art as a manager. Making due allowance for that small emotionally unstable section of Society which seeks to endow its favourites with deific qualities, most of Society has no real desire to encourage the cult of the superman as being necessary before being able to recognise the excellence of the artist. So it should be with management.

The sanctity of the individual

Too long it has been the fashion in our modern society to endeavour to submerge the individual and glorify all forms of totalitarianism and their monolithic concepts. The reasons are not far to seek. The biased propaganda of power organisations in all walks of life have, in the interests of those collecting greater power for the organisation, been lamentably successful in persuading people that regimentation is socially desirable. Some of the worst offenders are the Government through the Civil Service, the Employers and the Trade Unions. If Management by Consent is to succeed, positive efforts are essential to restore in public esteem the sanctity of the individual, a consciousness of the responsibility of Society to draw out of the individual those special attributes with which the individual is endowed by the Law of Infinite Variety, and, by placing these gifts willingly at the service of the community, add something to the sum of human well-being. We need to become aware of the great benefit to a dynamic industrial society of it being peopled by those who lead balanced lives. We need also to be acutely aware that great damage is done

to the efficiency of industry when its people are lopsided, unbalanced specialists, having their energies drained off in that way.

The task ahead

We can, as a nation, only maintain our position of greatness by being prepared for a radical shift in the relative values of its constituent parts. The old order has passed.

The greatness of Britain in the past was but a reflection of certain constituent virtues created from the sum of the special qualities of its individual citizens. In the formidable task ahead we shall need, even more than in the past, to draw upon all that each individual can contribute to the common pool of inspired and creative activity. The task cannot be done by proxy, in the form of power management of the many by the few; persistence on that course seems destined to lead to ultimate disaster. Today Britain is but one in the rapidly growing number of industrial nations, all of which will have access to all the technological developments such as those which we are considering at this conference. We are a small nation, considered numerically, and we have to hold our position against the competition of communities from 5 to 10 times our numerical strength. We cannot therefore risk being wasteful of any of the abilities and special attributes of our people. Our management of the future must be such that the individual is inspired and encouraged to make a full contribution. Only through Management by Consent does there seem any possibility of such an achievement.

A dependable people

One of the most important things to be accomplished is to create a conviction in the minds of our customers abroad that above all we are a dependable people, and that the flame of our creative genius, which in the past has set the course of many world fashions, is burning now with added brightness and intensity. The creation of that conviction is a matter of deeds, not words or propaganda.

Those directing Operation Britain can easily be defeated by the formidable propaganda agencies of the much larger nations, if the only substance behind Operation Britain is largely the brilliance of its propaganda. We shall demonstrate our dependability as a people only if it is observed, by those we wish to serve, that in our commerce and industry we employ higher standards of practice throughout their activities and relationships than are thought attainable by other nations. Our supplies of the essential raw material, the character of our people, are adequate for our needs; what is lacking is the managerial skill which will evoke its virtues and fashion them to serve a superlative purpose. That kind of managerial skill needs to be of a new order; the old has demonstrated its shortcomings in a most alarming fashion in recent times, and it will not be made to serve the nation's purpose by any attempted modernisatson or renovation of old techniques.

The era of automatic production

Automatic production seems the logical field in which to make a beginning with the development of the art of Management by Consent. Once it has proved effective in that field, the trickle of those using it successfully will rapidly increase to a stream, and even more rapidly will it become the main channel of new management practice in industry.

What is in mind may best be described by considering such a case as that of Rheinisch A/G fur Braunkohlenbergbau und Brikettfabrikation, Cologne. This concern is achieving the automatic production of coal with equipment costing £1,600,000 (equivalent to 2,408 man years of effort in design, construction and raw materials). It is operated by a crew of five men per shift and is reputed to be maintained by a staff of thirty.

It produces a volume of coal equal to that which in Britain requires 40,000 men. The commercial cost of this German coal is about 1s. 8d. per ton.

In popular terms this represents a small business regarded from the aspect of the number of men employed. But judged by the size of its production, it is a most important social unit with very great responsibilities. Because of these it can only afford to employ men of outstanding character and technological ability, and no doubt it pays commensurate salaries. Such a small but what must needs be a highly intelligent and economically independent group of individuals is unlikely to be readily amenable to "power" management.

Competent management

Surely any really competent manager, in the circumstances outlined above, would, in effect, employ Management by Consent? It is reasonable to suppose that in effect the situation would be similar to that envisaged in the illustration of the singer used earlier in this Paper. It is difficult to imagine a situation in which the awareness of taking part in creative activity was more acute or inspiring, and thus those involved would enjoy the full satisfaction of feeling the fulfilment of the urge of the dominant motive, the creative motive, and of the dignity of their contribution to the welfare of Society.

The intelligent "Manager by Consent" would surely ensure that not only was the purchasing power of such a staff adequate to meet all its reasonable needs and desires, but by the skilful management and variation of duties and hours of work, provide adequate opportunities for the useful employment of leisure and thus the full enjoyment of balanced living?

The balanced life

The individual would, by virtue of leading a balanced life, enjoy good health, physically, mentally and spiritually.

In time this pattern of living in industry would make a powerful appeal to an ever-increasing section of Society, resulting in a wider and more intelligent use of the technological opportunities ever becoming available.

Man would demand the opportunity of taking part in industry where this new management was the rule, and thus contribute his share to Society and the opportunity of living a creative balanced life, secure in the knowledge that he also would benefit in full measure.

When those in industry become aware that management, in the modern sense, is no longer "power" management applied by internal or external forces, but is consciously and unconsciously a service devoted to reaching higher standards of life for those being "Managed by Consent", industrial progress will, indeed, be swift, sure and beneficent and, by our present standards, incredibly efficient in its use of human energy.

Conclusion

Perhaps it will be considered appropriate to close this Paper with two quotations: "It is abundantly clear that there is something radically wrong with the structure and spirit of industry. Industry should be the servant of man. Somehow, industry has become man's master, dictating to him how he should live and what he must do. The nation has the right to look to the leaders in government, in industry and in the Trade Unions to evolve a method of government in industry whereby its problems may be solved by peaceful constitutional means rather than by recourse to the bitterness and dislocation of the strike action.

"The fundamental trouble in a great part of industry is a failure to solve the problems of personal relationships.

"Much of the fear and suspicion of the present day is the heritage of past victimisations by the strong over the defenceless. It should not, however, be too much to hope that men of goodwill in all branches of industry will appreciate the danger and make a determined effort to see industry as a whole in which each has a particular contribution to make to the common good." (The Bishop of Chester, quoted by *The Times*, 15.5.57.)

Finally, those inspiring words of Emerson: "God screens us ever more from premature ideas. Our eyes are holden that we cannot see the things that stare us in the face, until the hour arrives, when the mind is ripened—then we behold them and the time when we saw them not is like a dream."

It is in the hope that the ideas expressed in this Paper are not premature, and that the hour has arrived when ripened minds will turn them to public good, that I leave the matter for your consideration and discussion.

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NEW TECHNIQUES IN SHEET METAL FORMING

by JOHN A. GRAINGER, A.M.I.Mech.E., M.I.Prod.E., A.M.I.I.A.

Presented to the Birmingham Section of the Institution, 16th January, 1957.

Mr. Grainger was educated at Smethwick Technical College and served an engineering apprenticeship with W. & T. Avery Limited from 1918 - 1922. On concluding his apprenticeship, he remained with the firm until 1934, being concerned with toolmaking, tool design, factory layout and process planning.

In 1934, he joined The Perry Barr Metal Company as Chief Planning Engineer, and in 1936 moved to the A. C. Sphinx Spark Plug Company, where he held, successively, the appointments of Assistant Chief Tool Designer; Press Shop Foreman; Night Works Manager; Area Manager; and Superintendent of the Sheet Metal Division and Master Mechanic Plant No. 2 at Southampton.

In 1952, Mr. Grainger joined Rolls-Royce Limited as Senior Process Development Engineer and subsequently became Assistant to the Chief Production Engineer, until 1956, when he took up his present appointment as Chief Development Engineer at British Light Steel Pressings Limited.

He is the author of "Presswork and Presses" and has published many Papers on the subject of presswork and sheet metal forming. He was a member of the Sheet Metal Working Committee of B.I.S.R.A. from 1945 - 7957, and is a member of the Cupping Press Sub-Committee.

THE title of the Paper I was invited to present to you was suggested by your Chairman, Mr. Elkington, as "New Techniques in Presswork". I feel, however, that the title could more appropriately be "New Techniques in Sheet Metal Forming" as the dividing line, between pure presswork and other means of imparting forms to sheet metal, has become so wide as to be no longer clearly defined. It may be argued that "presswork" means what the name implies, viz. work performed on sheet metal by means of tools mounted in power (or hand) presses. This is a purist view. Is it strictly true, however ? Of recent years, much development work has been carried out to provide means of deforming sheet metal by the use of machines which employ tools constructed at a fraction of the cost of conventional press tools. As these efforts have been directed towards achieving the same result as that achieved by conventional press tools and presses, I feel it is only just that they be considered as part of press technique development.

This Paper, therefore, will not be devoted to orthodox presses and press tools entirely. In fact, the greater portion of it will deal with the less orthodox methods which, nevertheless, are considered as being future methods of high production — particularly if, and when, the machines and equipment have been developed to a state of perfection — and cheapness — as to make them more acceptable to industrialists as a whole as an economic

proposition. It is admitted that at the present moment they are, more or less, methods for the specialist industries. They should not be allowed to remain as such indefinitely.

In order to obtain a balanced view of these new methods, it may be as well to look briefly at the industry in retrospect.

A challenge to the craftsman

The manipulation and forming of sheet metal into complex shapes has for many years been a skilled art. It was practised for many years by hand methods and tools wielded by true craftsmen. After many years, the skill of these old-time craftsmen met a challenger in the form of machines designed for pressing into the sheet metal the forms, or shapes, that had hitherto been imparted by hand. These machines — the early power presses — were crude both in conception and construction. As experience was accumulated it was inevitable that fairly rapid progress was made. So much so, that the art of the pressworker began to rank with that of the sheet metal craftsman. Indeed, it was not long before the ingenuity of the pressworker was curbed by the fact that his art had advanced to such an extent that his techniques had outstripped the materials available for him to work upon. It is to be feared that this state has remained with us right up to the present time. No sooner has the metallurgist made available to industry a better quality material, than the press technician has devised better methods of manipulation, and so the spiral goes on. In some cases techniques have been devised which are beyond the scope of the available design of machine; and the machine tool designer has been forced to provide vastly improved machines or, in some cases, entirely new designs and types of machine altogether.

Concurrently with the improvements in tools, machines, and techniques, there have been improvements in die materials and lubricants to be used on the sheet metal to assist it in its transformation from flat sheet to formed product. Not every problem can be solved by passing it back to the metallurgist with the request "Give us better sheet metal". There must be a limit to the improvement in quality that can be achieved with known and tried materials. No one knows just how soon it will be impossible further to improve material quality to any useful extent.

This is the fact which has induced machine designers to give serious thought to the provision of machines operating on entirely new principles. It must be recognised, however, that these new machines could never have come into being had not the orthodox type of machine provided the fundamental data on which to base the design principle.

The first major step

The first major step forward from the orthodox type of press used for the deep drawing of sheet metal was the introduction of the triple action press. The advent of this machine, however, brought with

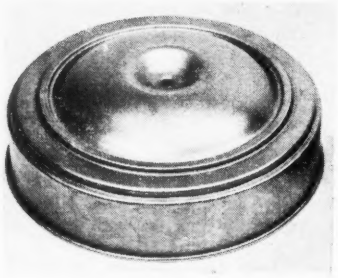


Fig. 1. Bottom holding pressure and precise control was essential to produce this article.

it its own problems. Tools were correspondingly more expensive and it became obvious almost immediately that this type of press would be suitable only for true mass production of parts which were not to be subjected to major modifications once they were tooled up — otherwise many very costly tools would be scrapped and production would not be an economic proposition.

A further point which detracted from the universality of the mechanical triple action press was the impossibility of varying the timing sequence of the slides. These were set to operate on a predetermined cycle built into the press. Much more versatility would have resulted had the third slide been arranged so that its timing could have been adjusted to suit varying conditions pertaining during the drawing and/or forming of different jobs.

This versatility can be obtained by fitting pneumatic cushions and control gear to mechanical double action presses. By the incorporation of such auxiliary equipment, a standard double action press is transformed into a triple action press with the added advantage that the cushion pad — taking the place of the third slide — can be brought into operation at any point in the drawing cycle in order to meet the conditions required at that point in the drawing cycle. Thus, it is possible to use the cushion to apply bottom holding pressure, to an already partly formed article, so that the form is not destroyed by the drawing and blankholding pressure.

The product illustrated in Fig. 1 was produced using this method. The whole of the form in the bottom of the product, contained within the square edge, was embossed in the flat blank and was then held between a pneumatic cushion pad and the punch head to prevent distortion under the drawing load. At the bottom of the press stroke the cushion pressure was neutralised; and then made operative again at the top of the stroke to act as an ejector. The cushion then remained pressurised for the next press cycle.

Not only can the cushion be used in this manner, however; it can be used actually to perform a part of the drawing cycle — as, for instance, in the compound reverse draw technique. In this technique,

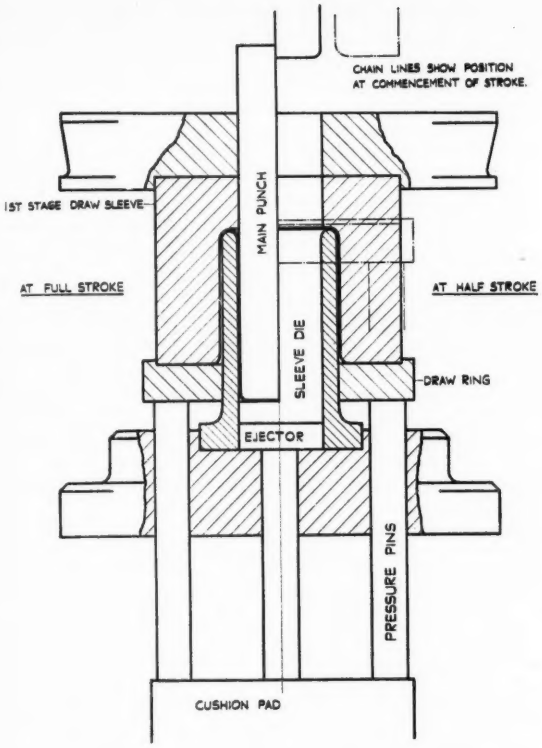


Fig. 2. Type of tool used for compound method of drawing.

the first drawing operation is actually carried out by the blankholder slide acting against the cushion pressure. The punch slide then carries on, in the usual manner, and completes the cycle by reverse drawing the cup, from inside the blankholder, into the hollow sleeve type die. By this method of deep drawing it is possible to achieve a much greater depth of draw in a single operation than by the normal drawing methods. In fact, tubular products can be produced in a single operation that would necessitate up to four operations by the normal direct re-drawing method.

A product resulting from a single drawing operation by this method is a tube with a closed end; the depth to diameter ratio is 2 : 1. The type of tool used for this compound method of drawing is shown in Fig. 2.

From these examples can be visualised the advantages of a controllable third slide. Work entailing bending, forming, piercing and plunging can, and has been, undertaken with presses so equipped.

New types of machine to use inexpensive tooling

In modern industry the most expensive item, in a manufacturing schedule, is time. Therefore, any process, or improvement in a process, that will reduce the time factor is to be commended. Indeed, on prototype work, any process that will reduce the time from completion of a design to the production of the "first one off" under production conditions is continuously sought after. With orthodox press tooling methods the greatest consumer of time is toolmaking; once tools are made and have passed the try-out and proving stage, however, production rates are high.

The "Marforming" process

With the object of reducing the cost of tooling for any deep drawn product, attention was directed — some five or six years ago — to developing a process that would utilise cheap tools. As the most expensive part of any press tool is the die, this is the item which received the most attention. It is always a difficult job to bed in a female form to a male form (the punch) and, should modifications be required during the development of the product, this expensive bedding in and matching up may have to be repeated two or three times. Therefore, it was considered, if some means could be devised whereby the necessity for a die was eliminated, an enormous saving in toolmaking costs would be effected and the time for production of prototype parts greatly reduced.

In the initial stages of the search for such a process the well-established, tried and proven, Guerin method offered a valuable lead. This method, used for the production of aircraft fuselage parts in light alloy, is so well known by now that a lengthy description will be omitted. It will be sufficient to say that the displacement of a rubber pad, under extremely high pressures, to cause it to conform to the contour of a die block placed between it and the press table, was a cheap way of producing shallow forms in flat sheet metal. Very deep forms or drawing operations were not very successful, as there was little or no control over the metal surrounding the punch, and puckering and wrinkling was experienced to a marked degree. This process, therefore, found its greatest application for bending the sides, piercing and raising the edges of the lightening holes in such parts as wing ribs, etc.

The comparative cheapness with which tools could be made for use in these "rubber pad" presses caused very serious thought to be given to the application of this method to deep drawing. Obviously the drawback which had to be overcome was the lack of control over the unsupported metal round the punch. By surrounding the punch with a steel (or cast iron) pressure plate to which was applied pressure from a hydraulic cylinder, this control was obtained. Further refinements, such as flexible control over the hydraulic pressure, resulted in a reliable method of deep drawing with very inexpensive tools.

This method of deep drawing and forming was originally known as the "Marform" process. A competitor to it is now known as the "Hydraw" process. They both use exactly the same principle but are marketed by different makers. The

"Marform" was originally produced as a "Packaged Unit", for use on existing hydraulic or powerful mechanical presses. It is felt, however, that the system can be operated successfully and safely only on hydraulic presses on account of the almost incompressible nature of rubber.

A universal die

In this method of pressing, the rubber pad is, in effect, a universal die which shapes itself under the applied pressure to the form of the punch and, in so doing, forms the sheet metal with it. The rubber pad in the top pad holder is built up from layers of comparatively hard rubber sheets — approximately 55 - 70 shore hardness. A punch is mounted in a fixed position of elevation on the bottom adaptor plate. This punch is surrounded by a blankholder plate of size just sufficient to pass inside the pad holder. The blankholder plate is mounted on top of a sealing plate — a permanent part of the equipment — which is a good fit to slide up inside the pad holder and prevent extrusion of the rubber outside the holder. Sealing plate and blankholder plate are supported on pins passing through the press bed down to the top pad of a hydraulic cylinder.

Presses of considerable tonnage capacity are required to operate this method of forming and deep drawing sheet metal parts; pressures much in excess of those required for normal methods of drawing. As rubber is virtually incompressible, and that used is fairly hard, considerable pressure is required in order to cause the rubber to "flow" to the form of the punch. Further, as the pressure plate surrounding the punch has to be compressed against the opposing pressure of the hydraulic cushion, a considerable pressure is also required here to cause movement. It is a logical statement, therefore, that the sum of these two loads is the total pressure wasted before any useful work can be carried out on the metal blank. This statement has been challenged — the argument being that the enormous pressure exerted is used to control the metal flow. It is agreed that the action of the rubber pad, under pressure, tends to lock the metal to the punch head and, therefore, restrain stretching of the material and so tends to ensure a more uniform thickness distribution on the finished product.

If one considers, however, that the pressure exerted on the ram of the normal mechanical, or hydraulic double action press is used in its entirety to cause plastic flow of the metal, then it is logical to consider all pressures in excess of this useful requirement as wasted. The extra pressure requirements can be judged from the fact that the smallest complete unit, of which the author has any knowledge, is a 1,000 tons pressure unit with a 900-ton cushion. The majority of machines seem to be in the 3,800-7,000 tons range, however, with cushion pressures (on the 7,000-ton machines) rising as high as 6,000 tons.

The principle of the "Marform" and the "Hydraw" processes is shown in Fig. 3.

Although, so far as is known, there is none of these machines installed in the U.K., considerable information is available and much investigation has been carried out to evaluate the claims made for them. It is claimed that the process combines the economy of the rubber pad press — (the Guerin process) — with the accuracy of the orthodox type of double action press equipped with conventional steel dies. The tools, consisting merely of a punch and blankholder, do not require the accuracy of fit that would necessitate precision machining. The punch only needs to be of accurate size and form to suit the limits called for on the product. The aperture in the blankholder can be band-sawn out to give up to $\frac{1}{16}$" clearance all round the punch form. Toolmaking costs are, therefore, very greatly reduced and the costly work involved in making matched contour female dies is eliminated. Materials used for the tools, too, are cheaper than conventional tools. For the blankholder plates cold rolled steel or boiler plate, surface ground, is quite suitable, whilst for the punch kirksite, zinc base alloy, and densified wood may be used in many instances, the choice, of course, depending upon the type of material being formed.

Basic essentials

The basic essentials which determine the drawability or formability of a component by the "Marform" or "Hydraw" process are the same as for drawing by conventional methods. A few variables, however, have to be taken into consideration. Owing to the clamping action of the rubber the minimum radius on the punch head can, in many cases, be slightly less than on double action press tools. On

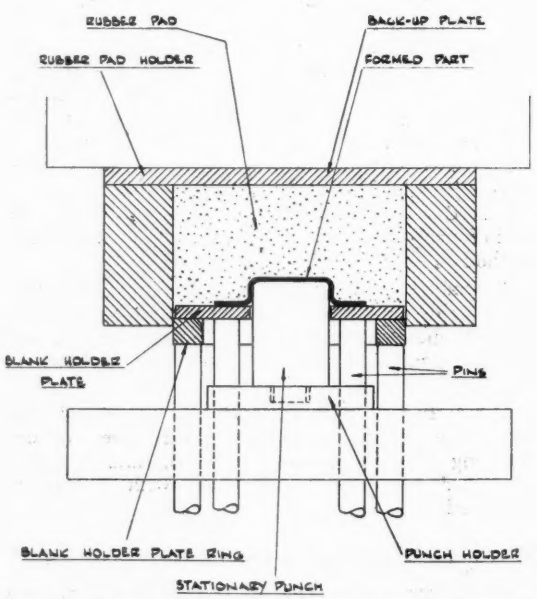


Fig. 3. Principle of the "Marform" and "Hydraw" processes.

the other hand, as the rubber pad itself forms the blankholding pressure there is a greater tendency for thickening up on the flange, and at the mouth, of cylindrical parts, and at the corner of radii on square or rectangular parts.

The material thickness, too, has an influence on the drawing or forming characteristics in a different manner than with steel dies in a double action press. Generally speaking, the medium gauges of metal (in the aluminium and aluminium alloys) will give greater depths of draw (material gauges 18 S.W.G. to 16 S.W.G.). The lighter gauges, however, seem to form more readily and with sharper corner radii than are generally possible on conventional tools and presses. They will not give the same depth of draw as the medium gauges, however. The heavier gauges (12 S.W.G. and over) seem to be less adaptable to this method of forming where maximum reduction is required. The possible explanation is the inability to control the draw radius forming itself on the rubber pad. Operating technique very closely follows that practised on normal double action presses. One point, however, is much more critical; the blanks must be kept entirely free from burrs, otherwise the rubber pad will rapidly deteriorate. It is bad practice in any method of drawing to have excessive burr on the blanks, but whereas these tend to be ironed out by the blankholder, on a double action press, they simply plough their way through the rubber pad.

The Hydroform process

Whilst the above process was being launched on the industrial world as the possible answer to the low cost tooling problem, development work had been proceeding on similar lines but a rather more advanced conception. This second attack on the problem

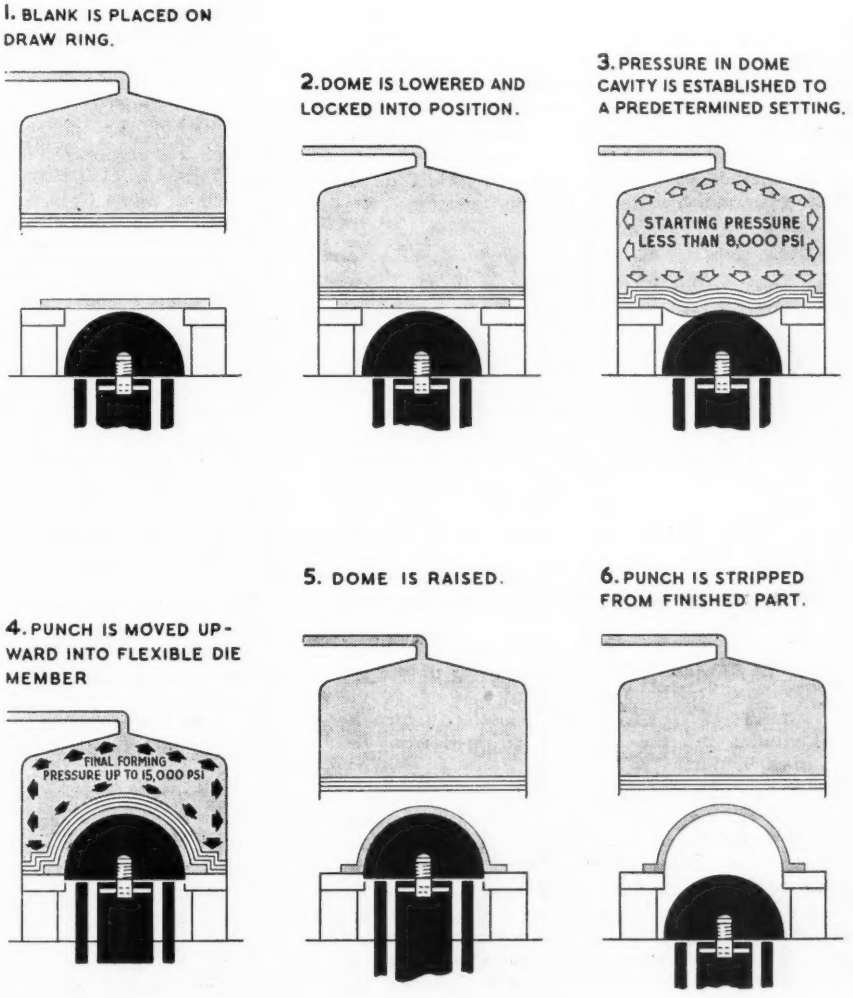

1. BLANK IS PLACED ON DRAW RING.
2. DOME IS LOWERED AND LOCKED INTO POSITION.
3. PRESSURE IN DOME CAVITY IS ESTABLISHED TO A PREDETERMINED SETTING.
STARTING PRESSURE LESS THAN 8,000 PSI
4. PUNCH IS MOVED UPWARD INTO FLEXIBLE DIE MEMBER
FINAL FORMING PRESSURE UP TO 15,000 PSI
5. DOME IS RAISED.
6. PUNCH IS STRIPPED FROM FINISHED PART.

Fig. 4. The six basic steps of the "Hydroform" method.

resulted in an entirely new type of machine for deep drawing and forming being introduced to the sheet metal fabricating industry in 1951. The process was termed "Hydroforming", presumably from the fact that the solid rubber pad or block is replaced by hydraulic pressure backing up a rubber diaphragm. This diaphragm is sealed to withstand the high pressures created by the hydraulic fluid — pressures which can rise to as high as 15,000 lb. per square inch. These extremely high pressures are not required for all materials or all shapes of product, therefore by using the appropriate pump control the pressure most suitable for any given part or material can be chosen.

The high backing up pressure behind the diaphragm is, of course, not a constantly applied load; the pressure when the diaphragm is not in contact with the workpiece is zero — otherwise the diaphragm would balloon and burst or, at best, tear away from its seals; neither is the total pressure in the cavity due entirely to pump action. Initial pressure in the cavity of the forming head of the machine, as supplied by the pumping unit, is up to 8,000 lb. per square inch. As the forming punch is driven upwards into the cavity, thus forming the sheet metal, the action intensifies the hydraulic pressure up to a maximum of 15,000 lb. per square inch. It will be seen, therefore, that the very action of forming the product creates its own pressure.

The method by which this intensification of pressure is obtained is fairly easy to understand.

The basic steps

The illustration, Fig. 4, shows in diagrammatic form the six basic steps in the operating sequence. They are as follows :-

1. The press head, or dome, containing the cavity is in its topmost position and a blank is placed in position on the blankholder ring.
2. The dome is lowered, with the diaphragm resting on the blank, and is locked in position.
3. Pressure in the dome cavity is built up to a predetermined load established for the particular operation (maximum 8,000 lb. per square inch).
4. The punch is forced upwards, by hydraulic pressure, into the dome cavity together with the metal blank.
5. Pressure in the dome cavity is neutralised, whilst the punch remains locked in its upmost position, and the dome is raised.
6. Pressure is released from the bottom hydraulic cylinder and the punch is stripped from the finished part.

To explain this in more detail, stage 1 and stage 2 of the operating cycle together consist of placing the blank to be formed in its set edge on the blankholder ring and then lowering the dome. This dome, containing hydraulic fluid at zero pressure, comes to rest gripping the blank between the diaphragm and the blankholder ring. When in this position, the dome is locked by means of four swinging collars of "C" form which swing into position between the upper face of the dome and the lower face of the press crosshead. Stage 3 is the raising of the hydraulic pressure in the dome cavity to the previously established value successfully to carry out the particular operation. The amount of this pressure is set on the controls and reproduces itself consistently at each cycle of the machine. At stage 4, which is the actual forming stage, the punch is caused to travel upwards, forcing the metal blank against the diaphragm which acts as a universal die. As the punch, and blank, are forced upwards the hydraulic fluid in the cavity is subjected to a great compressive load and the pressure is thereby intensified; again to a predetermined maximum which is maintained by a system of bleed valves which allow fluid to escape from the dome at established rates. These valves are operated by means of an adjustable drum cam. When the punch has been raised to the required height to complete the draw, it is locked in position.

Stage 5 consists of neutralising the pressure in the dome cavity and raising the dome to its top position, after the locking collars have been swung clear. Finally, stage 6 consists of releasing the pressure from the lower hydraulic cylinder, which causes the punch to be withdrawn from the finished part. This is left standing on the blankholder ring ready for removal by the operator.

One of the advantages claimed for the Hydroform process is that there is very little, if any, thinning of the metal being worked. This reduced thinning, it is claimed, is the direct result of the forming method. As the pressure builds up in the dome cavity, the metal blank is gripped very tightly between the head of the punch and the rubber diaphragm, thus setting up frictional effects which prevent slide, and consequent stretch, of the metal over the punch head. As the draw proceeds and the blank is forced into contact with a greater area of the punch form, this extra metal in turn is "locked" to the punch, and so on till the draw is completed.

This "locking" of the metal to the punch is also given as the reason for another advantage of the "Hydroforming" process, i.e. that bigger reductions per draw are possible and that only one or two operations are necessary instead of, perhaps, four or five.

The greatest advantage, perhaps, is the fact that tools consist of only two parts, a punch and a pressure (or blankholder) ring. The punch can be made from a variety of materials dependent upon the nature of the part being formed and the material from which it is to be produced. Materials from which punches have been made are :-

"Jabroc" impregnated timber ;
Hydulignum ;
Kirksite ;
tool plastic ;
mild steel ;
cast iron.

Naturally, for high strength materials, such as Nimonic, punch materials such as the tool plastics or

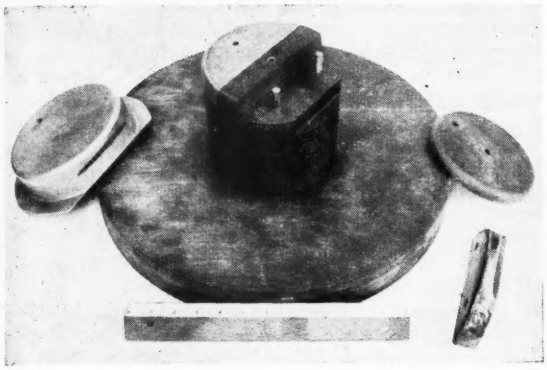


Fig. 5. Part incorporating an undercut produced in a single Hydroform operation.
(Courtesy of Vickers-Armstrongs Ltd.)

the densified woods would be useless as the high pressures generated in the dome would cause them to "flow" before forming of the blank had taken place. Neither would they be of very long life if used on thick material, say 10 S.W.G. and over. However, even if mild steel is used as a tool material, the cost of tools is greatly reduced for, as stated earlier, the most expensive part of a press tool set is the female member — the die — and with the Hydroform as with the "Marform" this member of the tool is eliminated. Close toolmaking tolerances are dispensed with, too, on the blankholder ring, as the aperture to fit over the punch can be at least one full thickness of metal clearance all round.

As the pressure medium is fluid and the "die" member (if we are allowed to call it such) is a flexible diaphragm, a moment's thought will lead one to the very obvious conclusion that returned forms and undercut forms are readily produced on the Hydroform machine. Where undercuts are to be a feature of the pressing these will of necessity have to be loose pieces, on the punch, which will be lifted clear with the pressed part and then removed for re-assembly on the punch in readiness for the next operation.

A part produced in aluminium alloy (20 S.W.G. L 59) in a single operation, and incorporating such an undercut, is shown in Fig. 5. The difficulties attendant upon tooling up and producing this piece by orthodox press tools in mechanical presses will be realised. To produce such a part in a single operation amply illustrates the versatility of the Hydroform method.

Although, when taking tool costs into consideration, the Hydroform is economically comparable with conventional presses even for fairly large quantities, it would appear that its greatest usefulness would be where comparatively short runs are the order of the day. This is particularly true of the aircraft industry. It is very often the case that a part, or parts, are needed in small quantities (rarely more than a hundred or two and seldom a thousand or over) and, to avoid manufacturing several expensive sets of press tools for conventional presses with the attendant wait of perhaps several months, these parts are fabricated by skilled sheet metal workers working to close tolerances. Should these parts be of reasonably intricate form, the number of skilled man hours expended on each may well run into a hundred or more.

As the tools required for the Hydroform are so simple, it is quite possible that their manufacture may entail no more time than that expended on a single product. Cycle times on the Hydroform machines vary from 180 cycles per hour on the smallest machine to 90 cycles per hour on the largest. Allowing for the operators' loading and unloading times, therefore, it would be practical to expect production rates to be between 120 and 60 per hour. At these rates of production the total number of any part required could be produced in less than a day's total operating time. In other words, for the total time expended on one intricate component by hand methods, tools could be produced and the total quantity of parts run off by the Hydroform method.

The use of the Hydroform is established in this country for producing parts for aircraft in such materials as aluminium and various of its alloys, mild steel (deep drawing quality) and stainless steel. Very little work, so far as is known, has been done using the high strength non-ferrous alloys — particularly the Nimonics. Some sample parts were produced in this material—Nimonic 75, in the U.S.A. — in order to compare the results of the process with parts produced by conventional methods.

Pressing a conical form

One of the most difficult forms to press successfully is, as almost every press worker knows, a conical form. As parts of this nature had been produced successfully in the U.S.A. from stainless steel, and were in current production from Nimonic 75 by normal double action press methods, it seemed ideal to attempt the same part on the Hydroform from the latter material. The stainless steel product was stated to be produced in one operation only on the Hydroform, and it was known that to produce the part by conventional methods in Nimonic 75 entailed six drawing operations, one planishing operation and seven anneals.

Attempts in the U.S.A. to produce the part in a single Hydroform operation failed for a variety of reasons. The main reason appeared to be that owing to the locking of the metal to the punch, described previously, there was considerably less stretch in the material and consequently the blanks, which were of the size used on normal mechanical double action presses, were too small by approximately $\frac{3}{4}$" on diameter. A secondary cause was that the higher strength, and consequent resistance to flow, of the nickel-chromium alloy made it impossible to form the centre portion of the pressing without signs of strain, or actual fracture, over the head of the punch. Slight wrinkles were also apparent on the cone.

Subsequently, attempts were made — still in the U.S.A. — to produce the part from blanks $\frac{3}{4}$" larger in diameter and by a modified technique which entailed two operations and the use of a steel hold down ring. It was also found necessary to resort to an interstage annealing operation following the first Hydroforming operation. Even by this technique, however, the process compared more than favourably with the normal press method with its seven operations, with interstage annealing between each operation.

On checking parts produced at this second attempt the following points were noted :-

The surface appearance of the parts was extremely good, there being no signs whatever of wrinkles, and the steps (concentric circles) usually associated with sequential redrawing were entirely eliminated.

Dimensionally the parts were well within permissible limits.

A thickness survey showed good metal distribution.

A hardness survey showed that the parts were much softer than those from the first attempt which ended in failure.

Fig. 6 shows the thickness and hardness distribution, in graphical form, on two of the successful Hydroformed samples compared with those on a sample produced by normal press methods.

Considerations to be taken into account

The cost of a 26" Hydroform machine is approximately £64,000. If this is amortised over 10 years, each year of 48 weeks and each week of 44 hours, we have an hourly charge of £3 0s. 7d. As there is as much of the machine below the ground as above, installation charges will be heavy owing to the excavations and reinforced concrete pit work. It is estimated this installation would cost a further £3,000, or a further charge of 2s. 10d. per hour. This gives a cost of £3 3s. 5d. per hour to amortise the total cost of machine and installation : a cost of 1s. 0.7d. per minute.

For conventional presses the cost would be about £6.000 per machine. Assuming that four operations are required by this method, the total machine cost would be £24,000. For these presses the installation cost should not exceed about £1,000 for the four, making a total of £25,000. This gives an hourly cost of £1 3s. 8d. : a cost of 4.7d. per minute.

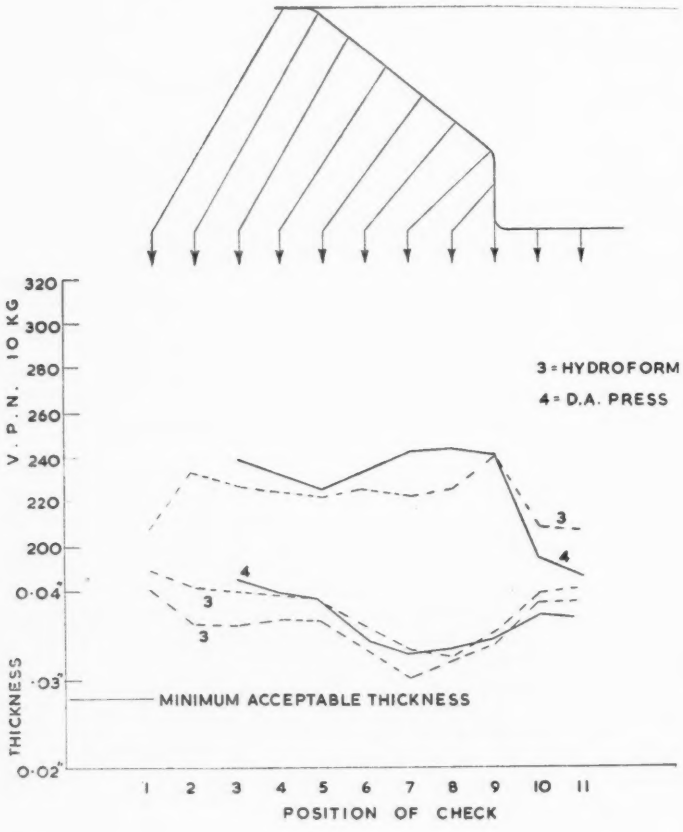


Fig. 6. Chart showing thickness and hardness surveys.

Power cost to run the machines would be of the following order :-

The larger motors on the Hydroform would have an efficiency of about 90% and the smaller motors on the conventional double action presses would be about 85%. The power factor in both cases would be about .9. As the cost of electric power is approximately 1d. per unit, the cost would be :-

Cost per hour = H.P. × .746 × efficiency factor × power factor ratio × cost per unit.

For the Hydroform machine this is :

Cost = 160 × .746 × 1.11 × 1.11 × 1d. = 12s. 5d. per hour = 2.48d. per minute.

For double action presses :

Cost = 80 × .746 × 1.17 × 1.11 × 1d. = 5s. 4.5d. per hour = 1.07d. per minute.

Although it is stated by the makers of the Hydroform machine that parts can be produced at the rate of 90 - 120 per hour, observations on an installed machine in this country indicate a lower rate. Assuming this is nearer 45 operations per hour, we have a time of 1.3 minutes per operation.

From actual figures on a difficult part in high strength nickel chrome alloy, a time of .6 minutes floor to floor time was established as average for conventional double action presses; therefore, the time would be 2.4 minutes for the four operations.

At an operator's base rate of 4s. 9d. per hour and a figure of 100% for the remaining overheads, this gives the following costs :-

Cost of producing by Hydroform —
1 operation — 2.5d.

Cost of producing by D.A. presses —
4 operations — 4.6d.

Tooling costs for the two methods, based on actual figures, it is estimated would be of the following order :-

Hydroform method —
1 punch only — about £75.

D.A. presses —
4 complete tools — about £500.

Basing tool cost on a total quantity of 1,000 parts, the tool cost per part would be :-

Hydroform — 1s. 6d. per part.
D.A. presses — 10s. 0d. per part.

These figures can be tabulated in the following manner :-

	One Hydroform	*Four double action presses*
Amortisation cost	1s. 0.7d. per min.	4.7d. per min.
Power costs ...	2.48d. per min.	1.07d. per min.
Production rate	1.3 mins. per op.	2.4 mins. for 4 ops.
Production cost	2.5d. per part	4.6d. per part
Tool cost ...	£75 — 1 punch	£500 — 4 tools complete
Tool cost per part	1s. 6d.	10s. 0d.

Taking all of the above into consideration, the following comparative cost per part can be made :-

	Hydroform	*D.A. press*
Amortisation cost per part ...	1s. 4.5d.	11.28d.
Power cost per part	3.25d.	2.56d.
Production cost per part	2.5d.	4.6d.
Tool cost per part	1s. 6d.	10s. 0d.
Total cost per part	3s. 6.25d.	11s. 6.44d.

Fig. 7 shows a group of parts produced in this country on the Hydroform machine and clearly indicates the scope of the process.

Attention is drawn to the two parts at the top left of this illustration. These were produced as an experimental exercise only, and were drawn together, i.e. one inside the other. An extremely good sliding fit was obtained. One of the parts is in 20 S.W.G. L 59 and the other is 14 S.W.G. DTD 571.

The Hydroform is not restricted to single operation work, as will be gathered from some of the foregoing remarks; Fig. 8 illustrates the use of the process on a two-operation job. The product from the first Hydroforming operation is shown standing on the forming punch for the second operation. As will be seen, the first drawn product is drawn slightly larger in diameter than the finished product, and in depth only as deep as the commencement of the projection on the side. When carrying out the second operation the punch is, of course, standing above the draw ring an amount equal to the depth of the first operation product, otherwise the unsupported pressing would be destroyed by the pressure of the hydraulic fluid in the dome cavity.

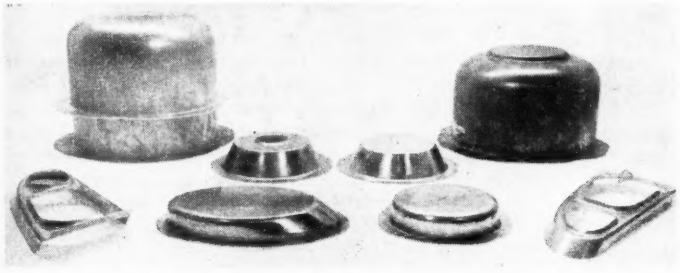


Fig. 7 *(above)*. Examples produced by Hydroforming (note the parts at top left, produced as an experiment). *(Courtesy of Vickers-Armstrongs Ltd.)*

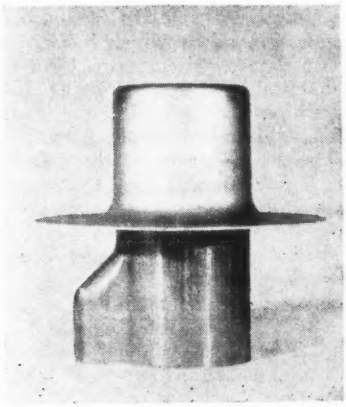


Fig. 8 *(right)*. Part from first draw in place on second draw punch.

Not only are plain walled and formed pressings possible but quite intricate shapes, incorporating ribs and raised beads; or embossed forms are readily and easily produced with sharply defined forms.

In case it is assumed that only cylindrical, or similar vessels are capable of production by this machine, an example can be quoted of a three-way junction piece with uneven sizes to the legs. In the production of parts of this nature, where raw material edges are presented to the rubber diaphragm, considerable damage may be caused and it is usual, therefore, to protect the rubber diaphragm by using a "slave" mat between it and the metal blank. Any cutting action will, therefore, take effect on the slave mat and so prolong the life of the much more expensive diaphragm.

Not only is the rubber diaphragm more costly than a thin slave mat, it is also more difficult to replace — even though the difficulty of the replacement operation has been reduced to a minimum.

A general view of the Hydroform machine is given in Fig. 9, although the actual complexity is not graphically portrayed; a vast amount of the machine and all of the hydraulic pumping gear is installed below the floor. The swinging "C" clamps to resist the terrific hydraulic loads are quite readily seen. When the crosshead of the machine containing the cavity has been lowered to position, these clamps swing in beneath the huge collars on the columns and so prevent lift of the crosshead against the intensified pressure in the dome cavity. At the left-hand side of the machine will be seen a number of slave mats ready for use.

"Dyzacking"

Following the same path, leading to cheaper methods of production, one enterprising company has resurrected an old technique, carried out a certain amount of development work to adapt it to the modern materials, and patented the result. This old technique is quite well known, to the older members of the press industry, as lead force drop stamping.

This technique is particularly suitable for short runs of parts, whilst permanent tooling is being constructed, and for the forming of some of the more difficult sheet materials, for instance, "Hiduminium 100" (S.A.P. sheet), titanium, Nimonic 75 and 80, stainless steel, etc. In fact, this has so far been the only method by which S.A.P. could be formed into cup shapes. Attempts to form similar parts, in this material, by deep drawing have proved a total failure. The lack of ductility and cohesion in this material make it totally unsuitable for deep drawing. The gentle stages of the "Dyzacking" process (as it is now known) seem to "coax" the metal into the die without setting up severe internal stresses to cause failure. The process is not entirely suitable for deep drawn parts with parallel walls; a generous draft angle is required in order that the component will remove easily from the die.

In this technique only a die is required — the place of the punch is taken by a lead force (commonly called a "cheese" by the operators of the process).

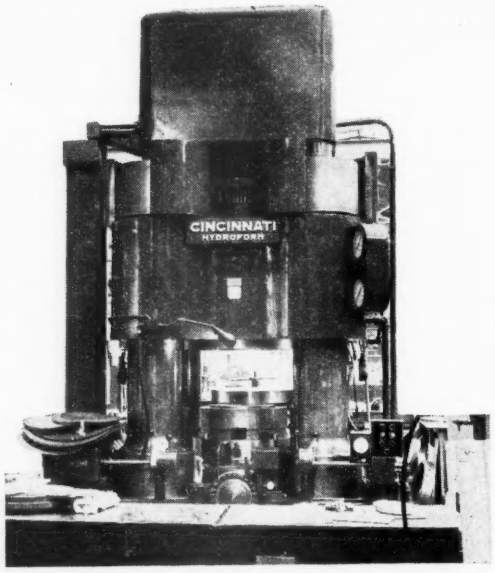


Fig. 9. General view of a 26" Hydroform machine — note slave mats at left.
(Courtesy of Vickers-Armstrongs Ltd.)

The stages in the process are these :-

The die is placed on the bed of the drop stamp and secured in position by the "dogs" placed in appropriate holes in the hammer block. The top of the die then has a sheet of metal placed over it and, upon this metal sheet, a cylinder made from sheet steel is placed and a seal is formed with some material such as plumbago. Into this cylinder molten lead is then poured until it is quite full and, when the lead has set to a pasty mass, the tup of the hammer is lowered on to it. The tup has criss-crossing vee grooves cut in its face and the lead is forced into these to secure it firmly in position. The sheet metal cylinder is then stripped off and a couple of sharp blows are struck on a flat plate finally to seal the lead in the grooves. This completes the preparatory work.

The tup is now raised and (after removing the plate) allowed to fall heavily on to the die once or twice. In this operation the lead is forced a little way into the die mouth to form the first punch form. To obtain metal clearance a blank of soft metal (such as brass or copper) of the same gauge as the metal to be used, is placed on the die and a further blow made. This forms the lead "punch" to the contour of the top of the die with the correct clearance for the metal.

The blanks of the correct material are then fed to the die and are struck by the tup as it falls, thus imparting to them the form of the lead force (or punch). After the quantity of blanks have passed through the first stamping operation, the lead force is again driven into the die, thus deepening the form

on its face, and the process repeated. This sequence is repeated until the required depth is obtained.

For comparatively small quantities of parts requiring several sets of tools, by normal press methods, this process is — on a cost basis — an extremely valuable one. Where a product would require only one set of draw tools, however, the advantages are so slight as to be almost non-existent. On multiple tool jobs, on the other hand, the advantages are so attractive that several thousand parts can be produced before the cost curves cross and the normal press method shows the advantage.

Perhaps the greatest advantage is the extremely short time taken from design of product to "first one off" by this method. It is being used quite extensively by the aircraft industry and, in some cases, by the motor car industry to obtain initial supplies of small (and often quite intricate) parts whilst waiting for delivery of permanent tooling.

Flow-turning

During the last two or three years a new method of producing close tolerance articles has become quite prominent. This new method is a development of spinning and promises to be one of the most revolutionary means of forming deeply contoured circular articles from thick sheet, or thin plate, metal.

This new development, it is believed, originated in Sweden for the production of dairy utensils in 18/8 stainless steel. It has now been taken up and developed further by the Germans and the Americans. According to the country practising the art, it is known variously by the names "flow-forming", "stretch planishing" or "flow-turning". All the forms are essentially the same, but are at various stages of perfection. In this newly developed process thick gauge material is made to flow plastically, by pressure rolling, in the same direction as the roller is traversing, and an article

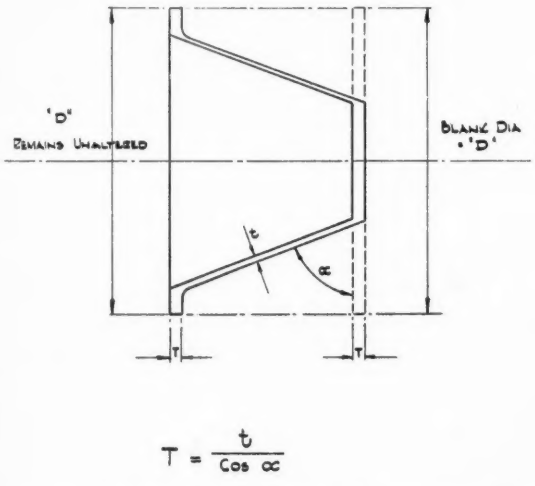


Fig. 10. Formula for obtaining thicknesses on conical parts by "flow-turning".

is produced whose thickness is very much less than that of the blank from which it is made.

As mentioned above, this new process appears to have been originally developed for the purpose of manufacturing seamless containers of cylindrical and/or conical form from thick sheet or light plate metal. Until quite recently it seems to have been restricted to the manufacture of 18/8 stainless steel buckets for the dairy industry, and for producing some types of 18/8 stainless steel sinks for kitchen sink units. Indeed, it would be reasonable to say that these were the only uses to which the process has been put in this country until recent months.

Although the basic principle is the same and the theories used for drawing blank thickness and reduction are essentially the same, the various engineers have their own methods of approaching the problem. Therefore, whilst the machines evolved all conform to an underlying principle, there are, of course, essential differences in their design and construction. All machines are essentially lathes but not of orthodox construction, although they all have two design features in common: the provision of extremely robust large diameter headstock bearings to withstand the high radial and axial loads imposed; and the use of hydraulic power to operate the tailstock spindle for clamping the blank against the chuck (or mandrel).

The main feature in which the three types of machine differ seems to be in the means adopted for traversing the roller and for obtaining the direction of travel.

As with orthodox spinning, the easiest shape to produce is a conical one. An essential difference between this new method and true spinning is that whereas in true spinning the aim is to retain the metal at its original constant gauge thickness, the deliberate aim in "flow-turning" is to reduce the material thickness considerably, in some cases up to 75%. Another feature is that orthodox spinning reduces the diameter of the blank as in deep drawing, but in producing a conical part by "flow-turning" the diameter of the blank is unchanged.

For "flow-turning" conical shapes the essential feature is that the axial thickness through both blank and finished shell remains constant. This, of course, leads to the premise that the thickness of the blank, as well as its diameter, must be precisely and accurately developed.

A simple formula is used to determine the blank thickness and can be expressed :-

$$T = \frac{t}{\cos A}$$

where :-

T = thickness of the blank
t = thickness of the side wall of the conical vessel, and
A = the angle between the wall and the base line extended.

Thus the depth of any conical vessel is not dependent on the thickness of the blank but only on the diameter and this, in turn, is dictated as the

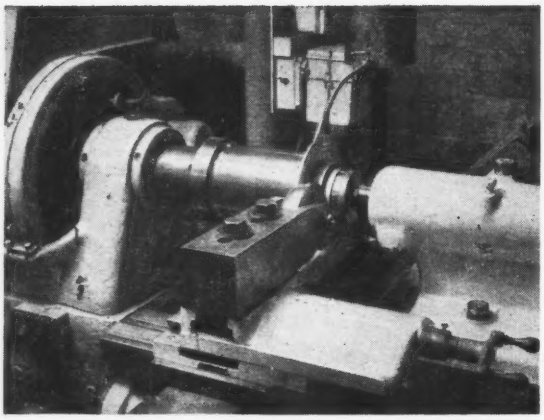


Fig. 11. Blank in position ready for spinning and " flow-turning ".

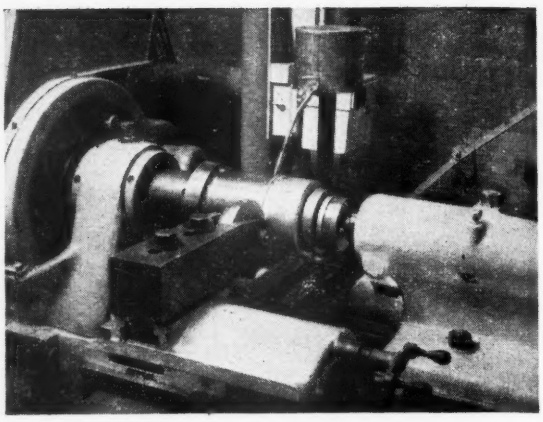


Fig. 12. The same blank after completion of the operation.

diameter of the large end of the cone. Fig. 10 shows, diagrammatically, how this arises.

From this formula it can be concluded that the production of cylindrical parts is impossible as the cosine of 90° is zero. Cylindrical components can be produced, however, by first forming a shallow cup from very thick gauge material and then flowing in the usual manner. The thickness of the blank used will depend on one, or both, of two things, i.e. the thickness of the base required in the product and the overall length of the finished product.

Providing that these two conditions fall within certain values, the cupping operation and the flowing operation can be carried out at a single pass using a specially designed roller. This is shown in Figs. 11 and 12. Fig. 11 shows a blank in position on an old lathe converted and equipped for experimental work, and in Fig. 12 the finished product can be seen after cup spinning and flowing at a single pass of the roller. The amount of reduction in metal thickness can be judged from the rim left intact at the top of the part. A further measure of the thinning may be gained from the fact that the finished experimental part is 6″ inside diameter and 5″ deep, whilst the original blank was only 9″ in diameter (material: L 16 aluminium).

The two conditions to be complied with in order to carry out this combined spinning and flow-turning operation are purely those of diameter and thickness ratios. They are: (a) the diameter (internally) of the finished cup must not be less than 60% of the original blank diameter; and (b) the thickness of the original blank must not be less than 1% of its diameter.

Since the advent of " flow-turning ", great strides have been made, and parts are being produced on a production basis that, two years ago, would have been considered impossible.

A modern machine, of German manufacture, is shown in Fig. 13. From the height of the operator

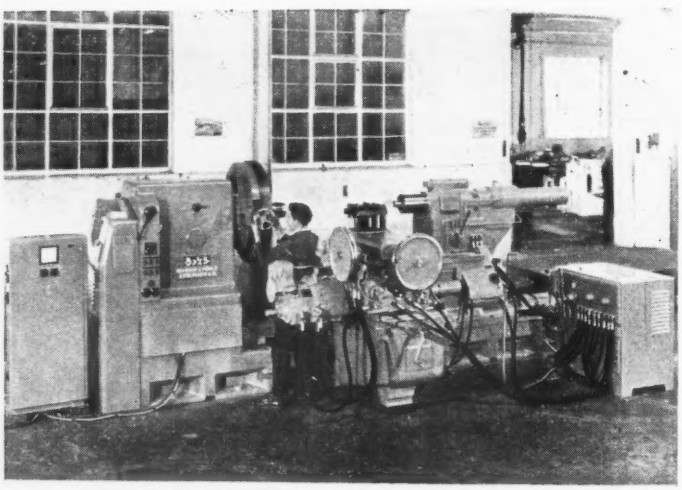


Fig. 13. A modern German heavy duty spinning and " flow-turning " machine.
(Courtesy of Elgar Machine Tool Co.)

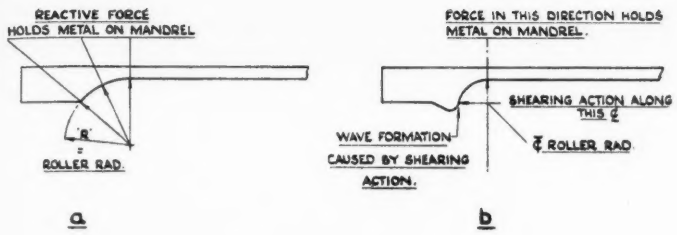


Fig. 14. Diagrammatic illustration of the importance of roller radius.

can be judged the size, and robust construction, of the machine. It was maintained a little way back that high radial and axial loads were imposed on the headstock bearings during the operation. Of these perhaps the radial load is the most vital as it can cause deflection of the spindle, and consequently affect the accuracy of the work to a considerable amount. Therefore, the spindle nose and the spindle bearings must be designed to withstand these loads. In the machine illustrated, the screwed nose of the spindle is in excess of 5″ diameter and the spindle is mounted in barrel bearings slightly in excess of 7″ diameter.

During experimental investigations and development work, a special tool (or roll) holder was constructed and fitted with strain gauges in order to measure the loads liable to be encountered under operating conditions. The loads measured were much in excess of those previously suggested, by some machine manufacturers, which were in the region of 9,000 lb. radial and considerably less axially. Actual recorded loads on 6 S.W.G. (.196″) material indicated a vastly different state of affairs:

On L 16 aluminium the loads were 4,500 lb. radial and 336 lb. axial.

On 70/30 cartridge brass the loads were 6,300 lb. radial and 292 lb. axial.

On Fortiweld steel the loads were 22,400 lb. radial and 9,650 lb. axial.

By calculating the area of the roller actually in contact with the material, the loading in tons per square inch was arrived at. The area in contact was calculated at .025 square inch. The radial load under the most extreme conditions — Fortiweld — is, therefore, seen to be approximately 400 tons per square inch. Hence the necessity for strength and rigidity.

When undertaking the flow-turning of any component, the reduction in thickness per pass of the roller must be taken into consideration; for this will influence the choice of radius on the working edge of the roller. The influence of this radius can be best illustrated when considering the flowing of truly cylindrical components.

For flowing to be satisfactory there must be no tendency for the material to be subjected to a shearing action, or to be lifted from intimate contact with the chuck.

Reference to Fig. 14 will explain, in some measure, the conditions set up with extremes of roller radius. As will be seen, if the radius, on the roller edge, should be reduced to the point where it coincides with the reduction in material thickness, there is no force to hold the surface material against the reactive force of the chuck. Therefore, at this point there will be a shearing action tending to force off the surface fibres of the metal. As the metal cannot actually shear along the whole length of the cylinder, a wave formation is set up which builds up in front of the roller. By varying the radius, therefore, the magnitude of the wave can be to some extent controlled.

On the other hand, if the radius is increased to exceed the reduction in thickness considerably, a condition is created in which all the forces imposed by the roller are actually tending to force the fibres of the metal towards the chuck and hold them in intimate contact. By striking lines radially, from the centre of the roller edge radius, it will be seen that they all impinge on to the chuck face where they are contained within the arc of contact with the metal cylinder. Preliminary trials indicate that the minimum radius on the roller must not be less than 1.5 times the reduction in thickness. A radius somewhat in excess of this minimum is to be preferred, however, and limited experience suggests that, for satisfactory flowing, a radius of 2.0 to 2.4 times the reduction is desirable.

Development of the radius will thus be seen to be of paramount importance. However, if advantage is taken of this variation in behaviour of material under the influence of varying radii, it is possible to produce parts hitherto considered to be impossible. By designing a trapping face on the roller, and a restraining member on the chuck, the wave formation can be directed in a definite path and caused to form (for instance) a flange out of the solid metal of the original cylinder.

Such a flange may be some way down from the open end of the cylinder or at the closed end, as shown in Fig. 15. To form a flange on the closed end, the technique of "reverse flowing" is employed. This means that the metal is made to flow in the opposite direction to that in which the roller is travelling. By this method the metal is made to extrude under the roller and travel backwards along the chuck. This can be achieved both when the roller is being traversed towards the headstock and away from it. The controlling factor is the means of securing the workpiece on the chuck itself.

Similarly, by providing some means of guiding the metal, produced by the wave formations, a curled bead (or strengthening rim) can be formed in a single pass of the roller. In fact, such a hollow curled bead must be produced in a single operation. Such a bead is shown in the illustration also. Actual examples of experimental parts, produced solely as an exercise, are shown in the next two illustrations.

Fig. 16 shows, on the left, a part in 10 S.W.G. 18/8 stainless steel from a 9" diameter blank cupped 6" diameter to a depth of 1½" and flow-turned in a single pass to a depth of 4". The wall thickness after flowing is approximately .040".

On the right is shown a part in deep drawing quality M.S. 6 S.W.G. again from a 9" diameter blank cupped 6" diameter to a depth of 1½". This was then flowed in a single operation to the form shown, including the flange which was formed from the wall of the pressed cup.

Both the parts shown in Fig. 17 were produced from blanks 9" diameter and of 6 S.W.G. material. The one on the left, in commercial quality copper, was produced from a pressed cup in one pass only of the roller. The hollow bead was formed from the wall of the cup and curled at the same time as the flowing was taking place. The piece on the right is L 16 aluminium and was again produced in a single operation from a pressed cup 6" diameter and 1½" deep.

Parts incorporating forms, not possible by pure flow-turning, can still be produced if premachined blanks are used. Thus parts with flanges at both ends, or machined forms, can be economically produced

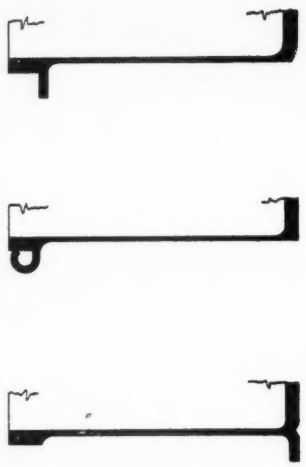


Fig. 15. Forms possible using principle at Fig. 14 (b).

instead of making a composite fabrication from sheet metal and forged rings welded together and finally machined to finished form.

One essential difference exists between flowing conical parts from thick sheet, and flowing cylinders. In the former case a chuck is required for each flowing operation and the cosine formula must be used to calculate the chuck angle and/or the wall (or base) thickness for each pass of the roller. One pass of the roller only can be employed for each flowing operation.

On the other hand, one chuck only is required when flowing cylindrical parts. The thickness of the wall can be progressively reduced by making a multiplicity of passes with the roller on the same chuck.

These examples and survey of some of the newer methods employed in the cold forming of sheet metals, it is hoped will be of interest.

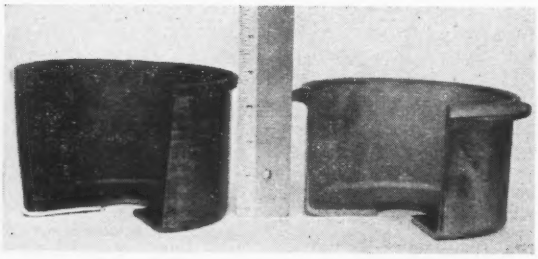


Fig. 16. Pieces produced as "flow-turning" exercises — *(left)* stainless steel ; *(right)* mild steel.

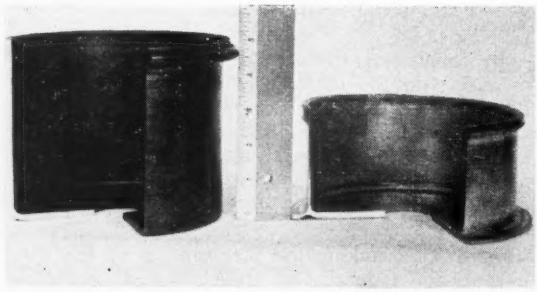


Fig. 17. Further exercises — *(left)* copper ; *(right)* aluminium alloy.

REPORT OF THE MEETING OF COUNCIL

Thursday, 25th July, 1957.

THE first Council Meeting of the 1957/58 Session was held at 10 Chesterfield Street, London, W.1, on Thursday, 25th July, 1957. The meeting, at which the Chairman of Council, Mr. H. G. Gregory, presided, was attended by 33 members, and Mr. J. W. Galyer, Honorary Secretary of the Luton Section, was present by invitation.

Before proceeding with the business of the meeting, the Chairman welcomed the newly-elected members of the Council.

Qualifications for Associate Membership (Article 15)

The Council discussed at considerable length the Article in question.

It was finally agreed that the matter should be referred back to the Finance and General Purposes Committee, and that it would receive further consideration at the next Council meeting.

Election of Vice-Presidents

The Council unanimously accepted the recommendation of the Finance and General Purposes Committee that Mr. J. E. Hill and Mr. G. R. Pryor be elected Vice-Presidents of the Institution.

Election of Standing Committees

The names of members elected to Standing Committees for 1957/58 appear on page 592 of this Journal.

Finance

The Chairman drew the Council's attention to the fact that when the budget for 1957/58 had been drawn up, no account had been taken of possible increases in postal and telephone charges, at that time only threatened, but since confirmed. The revised postal rates, for the Journal alone, would mean an increased cost per annum of approximately £1,200. In the circumstances, it was agreed that the budget be referred back to the Finance and General Purposes Committee for further consideration.

The Secretary assured the Council that a constant survey of costs was maintained at Head Office, particularly with regard to telephone and postal charges, and economies were effected wherever possible.

National Conference, 1957

The Secretary reported that the National Conference held at Harrogate from 30th June to 3rd July had been very successful, and had attracted an attendance of 630. The only criticism he had heard was that perhaps too much work had been compressed into the period available, and that more time could have been allowed for social intercourse.

Following the Council Meeting, a discussion took place regarding the procedure for future conferences, bearing in mind numerous suggestions which had been received.

Production Exhibition and Conference, 1958

The Secretary reported that arrangements were proceeding for the 1958 Production Exhibition and Conference at Olympia, which would be held between 12th and 21st May next. Lord Halsbury had agreed to be President of the Exhibition and Conference, and would also be Chairman of the Advisory Committee being set up to give guidance on organisation.

Institution Annual Dinner, 1957

It was announced that the Institution's Annual Dinner would take place on 4th October, 1957, at the Dorchester Hotel, London. The Guest of Honour would be Sir John Maud, G.C.B., C.B.E., Secretary to the Ministry of Power. (The Supplement to this Journal contains details and form of application for tickets.)

Society of Polish Mechanical Engineers

The Secretary reported that this Society had invited 15 - 20 members of the Institution to visit Poland on an exchange basis, early in September. It was agreed that the invitation should be accepted and that members of Council who would like to join this delegation should get in touch with the Secretary.

Membership

The Council approved a number of applications for membership and transfer, details of which appear on pages 609 - 610 of this Journal.

It was reported that the new form of membership certificate had now been agreed by the Finance and General Purposes Committee, and was being issued.

Appointment of Assistant Education and Technical Officer

It was reported that Mr. Ian King, G.I.Mech.E., Grad.I.Prod.E., had been appointed Assistant Education and Technical Officer to the Institution, and would take up his duties on 1st September.

Broadening the Base

The Council were informed that the Membership Committee's report on practical training was completed at the July meeting of the Committee, and would be submitted to Council at the same time as the revised examination structure being drafted by the Education Committee.

The Journal

The Editorial Committee were pleased to report that in spite of continually rising production costs, and by making judicious economies, such as using less expensive papers and adjusting some advertisement charges, it had been possible to complete the year ended on 30th June, 1957, without any deficit.

The advertising position was on the whole satisfactory, but more support was required from Institution members in order to offset the heavy increases in postal charges which would come into effect during the current year.

Institution Papers

The Papers Committee reported that Lord Hives had now accepted the Institution's invitation to present the 1957 Viscount Nuffield Paper in Bristol, in the early part of 1958.

Research Committee

The following reports were made on behalf of the Research Committee :

Materials Handling Group. The inaugural meeting of the Group was held on 21st May. A Materials Handling Convention will be held at Leamington Spa from 28th - 30th October, 1957 (details have already been circulated in the Journal Supplement).

A course, comprising 10 sessions on Materials Handling, sponsored by the Group, will be held at the Wolverhampton College of Technology in the autumn, and several members of the Group Committee will take part in the programme.

The Chairman of the Group Committee, Mr. A. G. Hayek, or his deputy, will represent the Institution at meetings of the Experimental Co-ordinating Committee sponsored by the Institute of Materials Handling.

Material Utilisation. No meeting of the Sub-Committee has taken place this quarter, pending the distribution of Notes for Guidance to Regions, Sections and affiliated firms. This circulation was made in July.

Sources of Information. Unfortunately, it was not found possible to have copies of the Directory available at the Harrogate Conference, but publication is anticipated in the near future.

Control of Quality. The Sub-Committee continues to hold regular meetings and are making good progress with their Report.

Joint Research Committee with I.C.W.A. A meeting of the Committee was held in May, when it was decided to proceed with investigations on "Electronics and Kindred Modern Developments as Applied to Process Loading" and "The Effective Use of Shiftworking in Industry". The Committee feel that the appointment of the Assistant Education and Technical Officer will greatly facilitate their research.

Standardisation

It was reported by the Standards Committee that following the report of their Sub-Committee on Unit Heads and Platens, it has been recommended to the British Standards Institution that investigations be initiated into their standardisation of unit heads.

A further Sub-Committee, on International Standards, is in process of formation.

The Annual Conference of Standards Engineers had been held, jointly by the British Standards Institution and the Institution of Production Engineers, on 9th May, at Church House, Westminster, London. A report of this meeting appeared in the July issue of the Journal.

The Committee continues its work of appointing representatives to serve on B.S.I. Technical Committees, at the invitation of B.S.I.

The Library

It was reported that the Library Committee intended to publish a supplement to the Library Catalogue, in the near future.

Region and Section Reports

The Council received a number of reports from Regions and Sections, extracts from which appear on pages 611 - 614 of this Journal.

Sections outside the U.K.

The Vice-Chairman of Council (Mr. H. W. Bowen, O.B.E.) reported that during the quarter a number of visitors had been welcomed at Head Office, from Sections outside the United Kingdom, including Australia and India. There was every evidence, from correspondence received, that the Sections outside the United Kingdom were continuing to promote the interests of the Institution with unflagging enthusiasm and vigour.

The Council were delighted to welcome, to the present meeting, Mr. Sam Downie, of the Australian Council, In a short address, Mr. Downie expressed his appreciation at having been invited to the meeting, and his gratitude to those members of the Institution who had made his stay in England such a happy one. It was not often that a member from Australia could devote so much time as he had done to meeting other members and engaging in Institution activities. He had done this deliberately, because many Australian

members did not have the opportunity of visiting headquarters, and he wanted to take back his impressions of the working of Council, and of the Membership Committee in particular.

Mr. Downie said he had been very impressed by the standard of the Harrogate Conference. In Australia they had been doing something on a similar line, and had had some success.

He had been able to attend a full day's meeting of the Membership Committee in Birmingham, and he had nothing but admiration for the members of that Committee. He had been amazed at the amount of work and energy devoted to the good of the Institution by the members of the various Committees.

Finally, he thought perhaps the most valuable part of his trip had been the opportunity to watch headquarters at work, so that when he returned home he would be able to give members in Australia a better conception of activities in the United Kingdom.

The Chairman asked Mr. Downie to convey good wishes from London to the members in Australia, and to accept the Council's thanks for the able way in which he had summarised his reactions.

Honours

The Council were pleased to note that Her Majesty the Queen had conferred the following awards on members of the Institution:

Knight Bachelor

Mr. William Scott, Member, Managing Director, Armstrong Whitworth Metal Industries.

M.B.E

Mr. R. G. Winton, Associate Member, Director and Technical Manager, Lansing Bagnall Ltd.

Obituary

The Council recorded with deep regret the death of Sir Alfred Herbert, K.B.E., Hon.M.I.Prod.E., and a Past President of the Institution. An appreciation appeared in the July issue of the Journal.

The deaths of the following were also recorded with regret:

Members: H. Gladney; E. H. Tremawan.

Associate Members: R. P. Davies; J. T. W. Edmunds; R. Hacker; J. Partington; S. R. Wood.

Date and place of next meeting

It was agreed that the next meeting of the Council should take place on Thursday, 31st October, 1957, at 10 Chesterfield Street, London, W.1, at 11 a.m.

ELECTIONS AND TRANSFERS

25th July, 1957.

ADELAIDE SECTION

As Associate Member
J. A. McMullen.

BIRMINGHAM SECTION

As Member
W. H. Curtis.
As Associate Members
G. Jones, L. M. Summerfield, R. J. Hall, E. D. Simmons.
As Graduates
R. Kumarachandran, R. E. Sykes, S. Das, J. H. Newall, M. W. Dodd.
As Student
R. A. Irons.
Transfers
From Associate Members to Members
H. W. Lawton, W. F. C. Bryant.
From Graduates to Associate Members
M. H. Warren, K. Tasker, A. C. Turner, C. W. Smith, J. E. Thorpe, J. K. Priest, D. E. H. Johnson, R. W. H. Bennett, G. E. Price, K. E. Myatt, P. H. Leyser.
From Students to Graduates
D. Harrison, D. W. Perkins, D. Cull.

BOMBAY SECTION

As Associate Member
N. Parekh.
As Graduates
V. G. Motwani, S. S. Mulgaonker.
As Students
J. D. Manivelil, P. S. Ahluwalia, K. N. Goswami, K. S. Khokhar.

CALCUTTA SECTION

As Associate Member
B. K. Mitra.
As Graduates
D. P. Batra, R. P. Ghate

CANADA SECTION

As Graduates
J. M. H. Heines, L. Butticci
Transfer
From Associate Member to Member
V. E. Crompton.

CARDIFF SECTION

As Associate Member
A. Ainsworth.
As Student
H. J. R. Hammond.

COVENTRY SECTION

As Member
V. W. Oubridge.
As Graduate
A. A. Gassor.
As Students
B. D. Haggar, D. J. Bateman, J. Shaw.
Transfers
From Graduates to Associate Members
L. B. Rutter, E. N. Coates, H. J. Moon.
From Students to Graduates
N. A. Tomkins, C. Kemp.

DERBY SECTION

As Graduates
R. W. Hile, I. A. Hunt.
As Students
A. Phillips, B. W. S. Nuttall.
Transfers
From Associate Member to Member
F. Wilson.
From Graduates to Associate Members
D. Duerden, G. C. Siddle.
From Students to Graduates
D. F. Tomlins, K. H. Davison, W. J. Rowland, N. Henshaw.

DUNDEE SECTION

Transfer
From Graduate to Associate Member
G. V. Shaw.

EDINBURGH SECTION

Transfer
From Student to Graduate
D. MacF. McDonald

GLASGOW SECTION

As Graduates
M. A. Doherty, J. B. Bryce
As Students
R. C. Blythe, E. C. Walker.
Transfers
From Graduates to Associate Members
J. G. Kerr, J. Hayes, W. M. Laird, D. Millar.

GLOUCESTER SECTION

As Graduate
G. H. Hines.
Transfers
From Associate Member to Member
A. J. Lissaman.
From Graduate to Associate Member
G. F. Lloyd.
From Student to Graduate
J. Newton.

HALIFAX SECTION

As Student
J. Rostron.
Transfer
From Graduate to Associate Member
R. Stephenson.

IPSWICH SECTION

Transfer
From Graduate to Associate Member
R. J. Hall

LEEDS SECTION

As Graduates
D. B. Hickie, J. W. Rhodes, D. White, F. R. Hobson.
As Students
K. Tomlinson, K. K. Sinha.
Transfers
From Associate Member to Member
G. C. Hepworth.
From Graduates to Associate Members
G. Metcalf, H. Trepte.
From Students to Graduates
N. K. Follows, D. Townsend

LEICESTER SECTION

As Graduates
N. R. T. Mattison, B. Roberts, A. V. Scott, J. B. Davies.
As Students
S. M. Chandaria, P. J. Walker, J. A. Rose, I. H. Jung, D. Marshall
Transfers
From Associate Member to Member
F. A. Duncan.
From Graduates to Associate Members
H. E. Hefford, R. F. Skidmore
From Student to Graduate
P. S. Agarwal.

LINCOLN SECTION

As Students
T. R. J. Reast, A. W. Medley
Transfer
From Graduate to Associate Member
D. Russell.

LIVERPOOL SECTION

As Member
A. H. Phipps.
As Graduate
R. G. Williams.
As Student
H. V. Holt.
Transfers
From Associate Member to Member
H. Mason.
From Graduate to Associate Member
F. Howarth.

LONDON SECTION

As Member
H. A. P. Disney.
As Associate Members
W. G. Panton, D. M. Sweet, D. S. James, L. C. Godfrey, R. F. Hitchcock.
As Graduates
L. J. Martin, N. Williamson, A. R. Fryatt, D. L. Wilson, A. E. Bamberger, C. A. Jones, D. L. M. Pickard, M. G. Dunthorne, E. J. R. Davies, H. C. Kisbee, K. J. Smith, B. W. Jenney, W. F. Maidment, K. J. Girling, J. E. H. Spencer, L. E. Lloyd, M. J. Evans, J. A. Dewart, J. H. Goldsmith, W. G. Whiteley.
As Students
J. E. Woor, D. K. Chatterjee, N. Ahmad, A. F. Minnis, M. P. Sood, R. E. Schofield, A. R. Dove, S. H. Morrall
Transfers
From Associate Members to Members
J. W. K. Murch, W. G. Marsden, E. A. Gordon.
From Graduates to Associate Members
J. E. Furse, H. Summerfield, S. Baker, E. A. Moore, F. J. Dobson, C. L. Aslen, C. W. Skidmore, L. A. Darby, H. Gray, R. F. Holmes, G. E. Wells, G. R. Pearce, G. W. Mason, G. M. Zelenka, J. G. Collyear, J. E. Taylor, E. W. Goody, L. F. Edmonds, A. M. Craig, S. R. Renew, F. G. Russell, A. C. Stoate, R. W. Butcher, P. A. Taylor, R. T. Mustard, A. E. L. Fenn.
From Students to Graduates
R. M. Turk, R. J. Crouch, R. J. Herbert, G. J. Thomas, D. R. Lawson, A. L. Fox, S. T. Suckling, A. R. Johnson, B. R. Boyle.

LUTON SECTION

As Student
P. N. Day.
Transfers
From Associate Member to Member
J. F. W. Galyer.
From Graduate to Associate Member
E. E. Allen.
From Students to Graduates
C. N. Johnson, J. N. Hullah.

MANCHESTER SECTION

As Member
A. J. R. Veale.
As Graduates
J. Singha, S. S. A. Duncan, R. Whitehead.
As Students
W. Barker, V. L. Retford.
Transfers
From Associate Member to Member
A. K. Thomas.
From Graduates to Associate Members
H. Maddocks, T. Laws, J. B. P. Wood, R. W. Allison, K. Johnson, D. G. Stretch, T. P. Callaghan, H. Bradshaw.
From Student to Graduate
J. R. Chisnall.

MELBOURNE SECTION

As Associate Member
P. J. W. Cottrell.

NEWCASTLE SECTION

As Associate Member
W. G. H. Fraser.
As Graduates
C. A. Stellakis, B. F. Willetts.
As Student
E. W. Hudson.
Transfers
From Graduates to Associate Members
G. Houlsby, K. Shield.

NORTHERN IRELAND SECTION

As Associate Member
W. Black.
Transfers
From Graduate to Associate Member
F. A. Smith.
From Student to Graduate
T. N. Magill.

NOTTINGHAM SECTION

As Member
F. Limb.

OXFORD SECTION

As Associate Member
N. Hope.
Transfers
From Graduate to Associate Member
K. F. Watson.
From Student to Graduate
M. H. Turner.

PETERBOROUGH SECTION

As Associate Member
J. Daniel.

PRESTON SECTION

As Graduates
J. Sumner, A. Wilkinson, J. Dewhurst, E. Stockdale.
Transfers
From Graduates to Associate Members
J. Finlay, J. Hartley.

READING SECTION

As Student
M. C. Reynell.
Transfers
From Graduates to Associate Members
A. G. Smith, H. Killingback, G. Graham.

ROCHESTER SECTION

As Graduates
R. W. Head, G. S. Peacock, J. E. Delo.
As Student
A. Barrett.
Transfers
From Students to Graduates
P. J. Varley, B. J. Wolford, A. Greig.

SHEFFIELD SECTION

As Associate Members
J. A. Webster, M. Harper, G. D. Jordan, G. C. Derbyshire.

SOUTH AFRICA SECTION

As Associate Members
E. A. W. Louw, G. A. Rous.
Transfer
From Associate Member to Member
D. E. Hamm.

SOUTH ESSEX SECTION

As Member
W. A. Mackenzie.
As Graduate
P. G. Ashford.
As Students
D. C. Harper, D. E. Weston.
Transfer
From Graduate to Associate Member
D. F. Fairweather.

SHREWSBURY SECTION

As Student
W. T. Birch.

SOUTHAMPTON SECTION

As Graduate
R. Russell.
As Student
A. C. Clegg.
Transfer
From Student to Graduate
C. G. J. Gould.

STOKE-ON-TRENT SECTION

As Graduate
P. Atkinson.

SWANSEA SECTION

As Graduate
W. S. Havard.
As Students
K. Bailey-Wood, T. D. J. Newton, G. G. Davies.
Transfer
From Student to Graduate
W. M. G. Evans.

SYDNEY SECTION

As Student
M. C. Stevenson.
New Affiliated Firms
Cleveland Machinery Pty. Ltd
Welded Products Ltd.
Gilbert Lodge & Co Ltd.
Nipard Pty. Ltd.
Norman N. Benson & Co. Pty. Ltd.
Demco Machinery Co. Pty. Ltd.
Transfers
From Graduates to Associate Members
J. C. Evans, C. L. Pyman.

TEES-SIDE SECTION

As Graduates
B. K. Fiske, J. E. Appleby, K. Hancock.
As Students
A. D. Best, C. Herrington, E. Kears.
Transfers
From Associate Member to Member
T. D. Walshaw.
From Graduate to Associate Member
K. Brown.
From Student to Graduate
K. Stokoe.

WESTERN SECTION

As Graduates
J. W. Fox, J. M. Williams, C. J. Hawketts.
As Students
G. R. Garratt, C. D. J. Parker, K. G. J. Ward, G. J. Calloway.
Transfers
From Associate Member to Member
D. B. Ebsworth.
From Graduate to Associate Member
M. H. A. Kempster.
From Students to Graduates
L. W. Hartle, L. J. Homer, D. R. Lewns.

WOLVERHAMPTON SECTION

As Associate Members
J. F. Holmes-Smith, G. G. Rowley.
As Graduates
R. J. Cattle, S. T. Pitt, W. A. Burns.
As Student
G. H. Birch.
Transfers
From Graduates to Associate Members
B. Harding, D. J. Curtis, W. H. Aston, V. L. Moffatt, L. E. Collins, W. Colley, B. Hollington, G. K. Mantle, D. Leek, E. G. Woodhall.
From Students to Graduates
C. J. Micklewright, B. F. W. Southall.

WORCESTER SECTION

As Graduate
J. D. Langford.

NO SECTION

As Member
J. Baines.
As Graduates
J. I. Ingram, N. Rushdi.
Transfer
From Graduate to Associate Member
R. E. Bullock.

EXTRACTS FROM

REGION AND SECTION QUARTERLY REPORTS

Presented to Council, 25th July, 1957.

EAST AND WEST RIDINGS REGION

Sheffield

Papers for Publication

Following the receipt of a letter from the Chairman of the Papers Committee on this subject, the Section Committee had an interesting discussion on means by which lecturers could be encouraged to prepare written Papers, which may be suitable for publication in the Journal.

This problem is rather delicate if there is to be no embarrassment either to the Papers Committee or to the lecturer, but suggestions for a satisfactory approach were communicated to the Papers Committee, who propose to circulate them to other Sections.

Election of Standing Committees

The Committee feel that serving on one or more of the Standing Committees is an important and necessary part of a member's responsibility to the Institution. Fortunately there have been many members willing to devote their time and experience to these duties, but there must be many more who could give equally valuable service. Section Committees who have members serving on the various Standing Committees are in the happy position of receiving first-hand reports of Institution activities and should, in their own interests, do whatever they can to persuade members to stand for election.

Sheffield Graduate

Five lectures were held during the 1956/57 session, with an average attendance of 64 at each lecture. Over the full programme 41 firms were represented.

During the period under review no lectures were held.

In planning the programme subjects are selected to cover the whole field of production engineering by selecting one subject from the following headings:

1. Management (Planning, Design, Inspection, Production Control, etc.);
2. Processes (Heat Treatment, Finishing, Welding, etc.);
3. Metal Cutting (Turning, Drilling, Milling, Blanking, etc.);
4. Basic Conversion Processes (Casting, Forging, Extrusion, Rolling, etc.);
5. Machines (Utilisation, Lubrication, Function, Installation);
6. Material Handling and Packaging (Storage, Handling, Mechanical Devices);
7. Production other than Metal Working (Glass, Plastics, Textiles, etc.).

One problem has been to convey to the members, in lecture form, the practical knowledge of the craftsmen in small companies which have no competent speakers. This has been overcome in many cases by contacting a company which supplies the equipment. This company can usually provide a speaker and has normal contacts with the production concern. The two in conjunction can usually provide a good demonstration and a well presented lecture.

EASTERN REGION

Ipswich and Colchester

The winter session of lecture meetings having been concluded in March has been the subject of much discussion at the Section Committee Meetings due to the small attendance at the lectures. It is anticipated that decisions will be made by the Committee which will assist in obtaining a much larger attendance of members and visitors at future meetings.

The Section Works Visit to Messrs. Crane Limited, Ipswich, was held in July. A further evening visit to the R.A.F. Station, Bentwaters, has been arranged with the Public Relations Officer, U.S.A.F., and this will take place during August.

An attractive lecture programme for 1957/58 session has been arranged, and this will comprise six lecture meetings, the first being a combined meeting with the Colchester Engineering Society to be held at Colchester.

MIDLANDS REGION

Birmingham

In April, the Graduate Papers Evening once again revealed that the high standard set in previous years was being maintained. The Chairman's Prize was awarded to Mr. J. Rawicz-Szczerbo for his Paper "Value Analysis". The Graduate Section Prize was awarded to Mr. J. Cheetham for his Paper "Introduction of Incentives to Plant Maintenance". The three other Papers by Messrs. L. E. Collins, R. Whately and W. R. Haywood were all highly commended.

In May, the Section acted as host for the Midland Region Conference "Tooling — Tomorrow's Production" at Edgbaston.

The Section held a summer Convention in June by invitation of the Directors at the works of Accles & Pollock Ltd., Oldbury. After luncheon and a tour of the works, the party visited Hagley Hall, the home of Viscount and Viscountess Cobham. The Section's Social activities are now being attended to by Mr. H. W. Lawton.

In concluding his term of office the Chairman, Mr. T. W. Elkington, thanked the Committee for its loyal support which had been reflected in the increased attendance at meetings and functions during the past session and wished Mr. R. N. Marland continued success in this direction. The effect of thorough programme planning and local publicity was now being appreciated. These had been submitted to the Editorial Committee for consideration. One of the Section's Graduates had submitted himself as candidate for the Schofield Scholarship, 1957.

Birmingham Graduate

With the close of another session we look back on a successful year with good attendances at lectures and works visits, also the meetings held at Kidderminster and Redditch in conjunction with the Worcester Section were very well attended, and it is intended to hold similar meetings at Stourbridge and Oldbury during the coming year.

At the Annual General Meeting, held in March, Mr. T. B. Wilcox was elected Chairman, and Mr. R. V. Whately, Honorary Secretary, for the 1957/58 session.

Five Graduates gave short Papers at the Graduates' Papers Evening held in April. The first prize was awarded to Mr. J. Rawicz-Szczerbo for his Paper "Value Analysis". Mr. J. Cheetham's Paper "Introduction of Incentives to Plant Maintenance", was judged a close second.

The Third National Students' and Graduates' Convention will be held at the University of Birmingham in September.

The theme for this Convention will be "Engineering for Existence", when well-known speakers will give Papers on the following subjects: "Organisation and Methods", "Cost Accounting", and "Production Methods Improved".

A full and interesting programme of lectures and works visits is being arranged for the coming session, with the hope of attracting a good attendance of both members and visitors. Social functions to be held later in the year, include a visit to the Farnborough Air Display, and a formal dance and buffet at the County Cricket Ground, Edgbaston, in December.

Coventry Graduate

At the Annual General Meeting, held in April, tribute was paid to the retiring Committee members, Mr. E. Emery, Mr. A. Hopkins and Mr. D. Wright, whose total years of service amount to 19. Mr. Emery had been associated with the Graduate Committee since 1948 and had filled almost every Officer's position at one time or another.

A Committee Social was held during May to which past, present and future members were invited and a very enjoyable evening was had by those in attendance.

The Section are indebted to The Standard Motor Company Ltd. for allowing some 25 members to visit the Tractor Plant at the Banner Lane Works, Coventry, during March. Members were conducted around the works and were allowed to study any particular aspect of the plant as selected.

The lecture programme for the forthcoming programme is now virtually complete, and embodies a variety of production subjects. By this means it is hoped that there will be greater support from the members and thus ensure a highly successful session.

Wolverhampton

The lecture programme for the past session and arrangements for the 1957/58 session have been completed satisfactorily. Wolverhampton will be the venue once again for the Regional Meeting in December.

Wolverhampton Section was amongst those which drew attention to the inferior nature of the Membership Certificate and the Committee are pleased that the draft which they submitted, as a suggested improvement, will for the most part be the basis of the future certificate.

Attention is being given to the possibility of holding a Section Summer Outing combined with a visit to PERA.

A very close link exists between the Wolverhampton Section and the Wolverhampton College of Technology. This spirit of co-operation is being extended to the newly-formed Materials Handling Group of the Institution. The advice of the Group Committee has been sought with regard to a special short course on Materials Handling which will be given at the College in the autumn term. It has been agreed that the course will be run in association with the Materials Handling Group.

NORTHERN REGION

Newcastle-upon-Tyne

The March meeting was very well attended when Mr. T. Nancarrow, G.I.E.E., A.M.I.Mech.E., A.M.I.Prod.E., presented a Paper entitled "Production Control for General Engineering at Home and in the U.S.A."

The Annual General Meeting was held in April at the works of Messrs. C. A. Parsons & Co. Ltd., and was well attended. The Chairman thanked Mr. C. Noble for the Chairman's Jewel of Office which he had presented to the Section, and expressed appreciation of the service which Mr. Noble had given over the years.

Mr. C. B. Abbey was elected Chairman for the session 1957/58 and Mr. H. B. Topham was thanked for his work as Chairman of the Section during the session 1956/57.

The Section Committee have been engaged on the preparation of the programme for the winter session and it is anticipated that a very attractive series of meetings will be presented. The subjects chosen cover a wide field in which the new industries to the North East are emphasised.

Tees-Side

Following the completion of the 1956/57 programme, a review of its success has been made and a number of changes proposed, which will be incorporated in the 1957/58 programme now being prepared. The Committee are particularly pleased at the number of junior applicants coming forward to join the Section.

NORTHERN IRELAND REGION

Northern Ireland

In January, Mr. J. Loxham, M.I.Mech.E., M.I.Prod.E., F.R.S.A., gave an extremely interesting lecture on the "Blending of High Quality with Low Cost in Engineering Production".

The lecture was extremely well delivered and illustrated with slides and films. The meeting was very well attended by both members and visitors and a lively discussion ensued.

The first part of the meeting in February was held as the Annual General Meeting (for members only). This was followed by a film kindly loaned by Messrs. Short Bros. & Harland.

This film proved to be of good topical interest, aircraft manufacture forming a reasonable percentage of local industry.

In March, the Section was honoured by the presence of Miss Anne Shaw, M.A., M.I.Prod.E., who, from her wealth of experience, gave a lecture on "Time and Motion Study" at the Belfast College of Technology, which was filled to capacity. This lecture was very well illustrated with films and slides, showing the effects before and after the introduction of time and motion study on particular applications.

A further interesting feature was the showing of examples of Memomotion Study. Miss Shaw was interviewed by both the Press and the British Broadcasting Corporation, the interview being reproduced by the B.B.C. in their next broadcast of the local programme "Ulster Mirror"; in this, a fair degree of publicity was given to the Institution.

The final lecture for the season was a new departure and comprised, under the heading "Safety in Industry", three short lectures on related subjects:

1. Insurance Claims (by a local Industrial Insurance Official);
2. Safety in Industry (by a local Safety Official);
3. Industry and Health (by an Industrial Doctor).

These lectures were very interesting, and through their relationship provoked probably the greatest degree of discussion that has been witnessed for some considerable time.

NORTH MIDLANDS REGION

Regional Report

During the last three months the Regional Committee have been preparing for the next one-day Conference, which will be held this year at Lincoln, on Saturday, 14th September. The theme of the Conference will be "Challenge of the Atomic Age to the Production Engineer".

Lincoln Section are very grateful for the help and co-operation they have received from other Sections in this Region during the two years they have held Regional Office.

Lincoln

During the period under review no lecture meetings have been held except the Annual General Meeting held in March. Arrangements for the next winter session are now well in hand.

Two extra members have been elected as members of Lincoln Section Committee. They are Mr. H. M. H. Fox and Mr. P. H. Roberson.

Nottingham

The Annual General Meeting of the Section was held in March, and all Section Officers were re-elected for a further term.

Reference must here be made to the whole-day visit to Vauxhall Motors Limited in May. This outing was a great success, and those who took part in it were highly appreciative of the welcome given to them by the management and staff of the Company.

At a meeting of the North Midland Regional Committee, the Chief Officers for the next session were elected from the Nottingham Section. They are: Chairman, Mr. L. Shenton; Secretary, Mr. C. N. T. Manfull; and Treasurer. Mr. C. H. Hodgkins.

The next event will take place on 14th September, when the Section will take part in the one-day Regional Conference to be held in Lincoln.

Peterborough

In addition to the activities mentioned in the Institution Journal and lecture programme 1956/57 a successful social outing to Warwick and Stratford-on-Avon was held on Saturday, 1st June, 1957.

NORTH WESTERN REGION

Regional Report

The North Western Regional Lecture was presented in April at the College of Science and Technology, Manchester, when Dr. Elliot Jaques gave a Paper entitled "The Analysis of the Relationship Between Production Engineering Work and Human Relations in Industry". The discussion was excellent.

Arrangements are now going ahead for the Fourth North Western Regional Dinner, to be held on 28th February, 1958. The President of the Institution, Lord Halsbury, will be present.

Manchester

The Section held the second lecture in the symposium on the "Application of the Computer in the Management Control", on Monday, 25th March, 1957. The lecturer was Mr. K. Tylden-Pattenson. A lively discussion followed an excellent Paper. Attendance was 48.

Mr. F. W. Cranmer, a long standing member of the Manchester Section Committee, has been elected Chairman for the 1957/58 session.

Manchester Graduate

The Section has had only one works visit during the last quarter and that was to the Broadheath Works of Messrs. Geo. Richards Limited, machine tool makers.

The Committee welcomes Mr. Marwaha, who has for some time been Honorary Secretary of the Western Graduate Section.

Preston

The last lecture of the winter programme, entitled "Varied Application of Drilling Machines in Relation to Production", was very ably presented by Mr. W. A. Hannaby, M.I.Prod.E., in March, at Blackburn, following the Annual General Meeting. A lively discussion ensued.

During the past year the attendance at lecture meetings has shown a distinct improvement and it is hoped that the trend will continue. It is proposed during the coming winter session to co-operate with the Barrow Productivity Committee in presenting a lecture at Barrow. This will give members in one of the more remote parts of the Section a chance to actively partake in the Section's activities.

Membership of the Section has shown a promising increase especially in the junior grades of membership, which augurs well for the future.

The Section Committee feel that more contact with Section members could be beneficial to all concerned, and ask members to communicate with them, through the Secretary, on any matter that may be of interest.

Stoke-on-Trent

Mr. W. R. Bailey, the Honorary Secretary, has recently returned to the district after attending the PERA course for his firm, and has resumed his duties as Section Honorary Secretary. During Mr. Bailey's absence Mr. A. McDonald has been acting as Honorary Secretary.

The 1957/58 lecture programme has already been compiled, the Section being fortunate in receiving an affirmative answer from each lecturer who has been approached in the first instance. Arrangements are now in hand to receive Mr. Cooper, the Education and Training Officer, in the autumn, when he will visit the North Staffs. Technical College and four of the leading industries in the area.

SOUTHERN REGION

Oxford

During the last period the activity of the Oxford Section has been to complete by three further meetings the yearly programme laid down for the Oxfordshire area.

Based upon the theme of "Materials", a further four meetings have been held since the last report, namely, "The Use of Rubber in Engineering" by Mr. A. N. Gent, B.Sc.; "Material Control" by Mr. W. E. Stanley, A.C.W.A.; and "Tube Work and Manipulation" by Mr. L. C. Hackett, Technical Director for Messrs. Accles and Pollock Limited.

Following on discussions by the Oxford Section Committee during the last two sessions, a definite policy of taking production engineers' meetings to various localities in the vicinity of Oxford has proved to be most helpful and conducive to lively interest and discussion in the area.

Meetings have been held in Oxford, Banbury, Witney, Aylesbury and Bicester, and this method of arranging the season's meetings will be continued for the coming year.

It has been decided that continuity of future programme arrangements shall continue throughout the coming season by adopting the theme of "Development of Modern Manufacturing Techniques", to cover a series of eight meetings.

These meetings will be arranged at convenient centres throughout the Oxfordshire area.

Applications for membership during the year have shown a marked increase, and the Oxford Section Committee have every expectation of continued progress both in the value and standard of the meetings arranged, and the growth of the Section during the coming year.

Southampton

Next winter's lecture programme will concentrate on local speakers and a very encouraging response has been forthcoming from all firms contacted. The Committee are pleased to report that the programme is now finalised to their every satisfaction.

The Section Committee are now very active in making arrangements for the Sixth Aircraft Conference at Southampton next year, and further details will be announced as soon as the programme is completed.

SOUTH EASTERN REGION

Luton

During the period under review, the Section has completed a lecture programme, which has been more successful than those in the recent past. The programme policy of lectures being connected by a central theme appears to offer more attraction to both members and visitors, and certainly gives continuity of interest.

Arrangements are going ahead for the 1957/58 lecture series, for which the theme will be "New Tools for Production Engineers", and a very interesting group of lectures should result.

Reports from these members continue to be regularly received at Section Committee Meetings.

Luton Graduate

The past year can be considered a successful one. Activities consisted of four lectures, three works visits and a Graduate Evening.

The most popular event was the lecture given by Mr. B. S. Pearn, of Taylor, Taylor & Hobson, on "Optical Tooling", where members learnt of the various applications of the latest equipment in this field.

The visit to Borg Warner Limited in February, although held during petrol rationing, attracted sufficient members to fill more than the allotted number of places.

The Graduate Evening drew increased support in the number of Papers presented and has confirmed the Committee's opinion that the reading of 10-minute Papers should be encouraged. It is proposed that next year's Graduate Evening should terminate in a general discussion between members on topics of common interest.

The Committee's aim for the coming year is to improve co-ordination with the Senior Section.

SOUTH WESTERN REGION

Cornwall

Activity in the Cornwall Section during the summer months is nearly always confined to Committee Meetings and the preparation for the coming winter.

This year is no exception and the last lecture meeting was held in April at the Cornwall Technical College in conjunction with a special course on automation.

An attractive programme is being arranged for next winter and it is hoped that the session's work will be crowned by a very successful Second Compressed Air Conference being planned for next Easter. Members will appreciate that owing to the international situation very elaborate plans were hastily postponed at the beginning of the year. Now that the situation in Suez is somewhat settled, it is hoped that next Easter a record attendance at Camborne will be forthcoming.

Western

The last meeting of the season was a film show at the Bristol Aircraft Company's factory at Weston-super-Mare. There was a good attendance and obvious enthusiasm. Because of this support two meetings will be arranged at Weston in the 1957/58 programme.

The Section Committee were very pleased to welcome Mr. Woodford to the meeting in May and derived much benefit from his explanations and guidance, particularly in respect of applications and the future outlook of the Institution.

The Committee are also glad to report that Bristol University are now taking an academic interest in aspects of production engineering. It is early days, but at least a start has been made and the Committee are hopeful of bigger things in the future.

WELSH REGION

Regional Report

The Regional Committee during the last few sessions have been very actively engaged in preparing for a proposed one-day Conference which, it is hoped, will be held in the South Wales area in April, 1958. The Conference will be run on the lines of syndicates and all the main subjects have been chosen together with the complete synopses of each one. As this is likely to be the first Regional one-day Conference in South Wales, very great care is being taken to ensure the success of the Conference.

The Committee have also been dealing with the technological education aspects in the South Wales areas, and through both of the Section Committees significant strides have been achieved in recent months.

Swansea

The Swansea Section was very glad to have one of the first opportunities of meeting the Institution's Educational Officer, Mr. F. W. Cooper, who recently visited the Section for the purpose of extending the aims of the Institution in this area by making the necessary arrangements for better facilities to be made available at the Swansea Technical College. As a result of this visit there appears no doubt that after many trying times, the education of production engineers will be adequately provided for in the future.

The Swansea Section have also taken a very lively interest in the proposed forthcoming one-day Conference to be held in April, 1958, and they are looking forward to seeing the results of their recent deliberations.

It is very gratifying to know that during the past session the local press have reported practically every meeting that has been held. A very interesting and satisfactory works visit was paid to Messrs Girlings, of Newport, and it is hoped that all our works visits will be as enjoyable and as instructive as this one.

SECTIONS OUTSIDE THE UNITED KINGDOM

Calcutta

The 11th Annual General Meeting of the Calcutta Section was held in May, when Mr. P. Bhattacharji was re-elected as Section Chairman. Messrs S. T. Chatterjee and H. N. Ghosal were unanimously elected as Section Honorary Secretary and Section Honorary Treasurer respectively. Messrs. T. R. Gupta and S. P. Roy were elected as members of the Committee in the vacancies caused by the retirement of Mr. S. R. Chatterjee and resignation of Mr. S. Bhattacharjee. Mr. P. J. O'Leary was re-elected as a member.

Three Section Committee Meetings were held during the quarter under review.

Melbourne

At the March meeting a Paper entitled "Educational Trends for Industrial Technology" was presented by G. P. Taylor, B.Sc., M.I.Prod.E., Head of Production Engineering School, Royal Melbourne Technical College. Mr. Taylor outlined to members how his course in Production Engineering covers subjects for the Institution and new educational requirements for future production engineers.

At the meeting in April, Mr. D. L. Beattie, Officer of the Division of Industrial Development, presented a Paper entitled "Efficient Materials Handling". This was supported with a colour film on Materials Handling Methods.

Members made a works visit in April to the factory of H. J. Heinz Ltd., Dandenong.

In May, members heard a Paper, "Modern Industrial Furnaces", by C. D. Ashton-Martin, who has spent a considerable time overseas studying industrial furnaces.

Melbourne Graduate

In March, the Section visited Russell Manufacturing Co., Richmond, which is the second largest company in the Repco Group. Products manufactured by the Company include pistons, piston rings, piston pins and valve guides. Emphasis was placed on automatic machine tools and their application, the new die casting shop and chrome plating departments in the factory. The visit was one of extreme interest.

At the works visit to Standard Vacuum Refinery Co., a working example of automation was demonstrated. The layout of the refinery was most interesting, particularly the excellent amenity block.

A works visit was made to Herald-Sun Newspaper Office, Melbourne, which is one of the largest newspaper offices in the Southern hemisphere. Members were shown all facets of newspaper production and the many problems which confront the production personnel in producing the paper to a very tight schedule.

This visit was of great value and extreme interest.

Sydney

A policy of presenting lectures of varied and general interest has been pursued this year. Following "Some Aspects of Apprenticeship and Training in Western Germany", presented by Mr. A. E. Newcombe, M.I.Prod.E., Mr. B. A. Hadley, B.E., Senior Inspector of the New South Wales Government Mines Department, spoke on the dredging, production and separation of minerals, principally zircon and rutile, from "Black Sand" found on Australia's eastern coast beaches.

This lecture, touching on a subject of wide public interest — and concern, because it affects areas jealously guarded as pleasure resorts — was extremely well received.

In May, a Paper "Preventative Maintenance as a Cost Reduction Tool" was presented by Mr. A. J. Littlejohns, Production Planning Superintendent of Q.A.N.T.A.S., the Australian owned international airline.

Mr. K. Jones, A.M.I.Prod.E., discussed Materials Handling, and showed an appropriate film in his address on "Materials Handling in Engineer Workshops" for the June lecture.

Equally interesting and varied subjects with competent speakers are set down for the remainder of the year's programme, together with a Residential Conference arranged for early October at the South Coast resort of Kiama.

The Section Chairman, Mr. S. E. Downie, is now in the United Kingdom, and is visiting the Headquarters of the Institution.

THE 8th ANNUAL SUMMER SCHOOL

24th-28th JULY, 1957

THE stated function of the Annual School is to provide facilities for an interchange of views on production engineering problems between those responsible for education and training and those engaged in production in industry, and to this end the theme of "Operational Research" was chosen for this year's School. Enough sound work in this subject is now taking place in several of the major firms and in one or two of the universities to ensure that a sound team of lecturers would be available not only to clarify the present position of Operational Research, but also to give specific applications to members of the School from industry. As the Institution is including the subject of Applied Statistics and Operational Research in its new structure for the Associate Membership Examination, it was thought that interest in providing suitable courses in technical colleges and universities would be stimulated among the teaching members present.

The School was again held in the delightful house and grounds of Ashorne Hill, near Leamington, and full use was made of all the excellent facilities. Some alterations to buildings have been made and those accommodated in the Stable Block can but congratulate the Iron & Steel Federation and their architect on a most imaginative and, indeed, a beautiful cloister-like block of bedrooms.

The student members numbered 90, coming from as far away as Glasgow and Larne, roughly two-thirds being from industry.

Prominent guests

It was pleasing to have as guests of the School Mr. and Mrs. S. Downie and Mr. and Mrs. F. J. Allen, all of Australia, Mr. Downie being Chairman of the Sydney Section and Mr. Allen an Inspector for Technical Education. Mr. R. S. Odd, Director, Wilmot Breeden Ltd.; Mr. H. G. Gregory, Chairman of Council; Mr. S. L. Whitby, H.M. Inspector; and Dr. N. A. Dudley, of the University of Birmingham, were also able to spend a little time with the School. Mr. E. W. Hancock, Immediate Past President; Mr. R. Ratcliffe, Immediate Past Chairman of the Education Committee; Principal C. L. Old; and Mr. H. W. Hodson did the work of Chairing for the various sessions. The staff of the Institution was led by Mr. W. F. S. Woodford, the Secretary.

Modifications to the more usual programme included two lectures in each morning session in order to cover the wide field of Operational Research, and there was also a presentation of apparatus and case studies on two evenings.

Expert and executive

Dr. T. E. Easterfield, of D.S.I.R., gave an introductory lecture on relationship between expert and executive with especial reference to Operational Research, stating that the former has, or has means of getting, intensive knowledge in a limited field, the latter a broad grasp of all aspects including policy. The expert thus has comparative freedom from commitment, an absence of responsibility for executive decisions and the possibility of giving impartial assessment of particular aspects of operations. The relationship can only be efficient if the two parties respect each other's approach and keep in constant communication. Dr. Easterfield defined Operational Research as scientific research into the operations of a going concern, carried out for and in collaboration with the executives of that concern. The Operational Research worker being an expert in the above sense has the ability to study as a scientist the structure of what is going. Though particular techniques are frequently used in Operational Research, these are ancillary to the basic task of analysing operations as a whole.

The real work of the Conference was initiated by Mr. F. Benson, Lecturer in Applied Statistics at the University of Birmingham, who dealt with the details of Operational Research stating that the first step in an investigation, namely, that of formulating the problem, was often the most difficult. After this, construction of a model (often for flexibility in a purely abstract form, for example, mathematical) would lead, though not invariably, to a solution which when tested and controls established could be put to work. He gave as an example of mathematical tools used, Probability and Statistics, Theory of Queues and Linear Programming. Dr. K. Pennycuick, of Imperial Chemical Industries Ltd. spoke on Plant Balance and of the successes Operational Research teams have had in arranging, say, a pattern of production to give acceptable overall plant utilisation or additionally to show the need for more capacity or even the closing down of surplus equipment. He presented to the discussion groups a problem based on plant utilisation which was admittedly a teaser and it is to the credit of the groups that they got anywhere near a solution in the time available.

The third day found the School slightly battered, but Mr. H. G. Jones, of The Steel Company of Wales, omitting the mathematics, gave a most interesting and lively account of Operational Research for the ultimate capacity of a slabbing mill, firstly by experiment to discover the factors that determine capacity of the mill itself and secondly to examine the auxiliaries and often to reveal the serious effect they have on overall capacity. That his team is working on probable conditions in 1960 gave the School an insight into the long-term planning necessary for so large and expensive a plant. Dr. S. Eilon, of Imperial College, followed his lecture on Selection of Lot Sizes in Batch Production by setting the groups

a series of questions to bring out such points in his lecture as the various criteria of optimal performance and the significance of a production range, all applied finally to a multi-product schedule. It would seem from the brisk discussion that followed that the 1958 School might well be again on Operational Research, but dealing specifically with planning control.

Saturday found the School knowing the (mathematical) worst, but excellent lectures by Mr. Stafford Beer and Mr. R. S. Gander, of The United Steel Companies, considerably eased any worries. Mr. Gander, giving what could so easily have been a dry summary, but which certainly was not, reviewed Operational Research being undertaken by many large concerns in Great Britain and also went some way in elucidating the mystery, if indeed it is a problem, of where Work Study ends and Operational Research begins. Mr. Stafford Beer, taking as his subject the Cybernetic Model and its implications for the future took as typical systems, and in ascending order of complexity, the layout of a machine shop, the control of quality, production control and the company. The first he defined as relatively simple and deterministic, the last as exceedingly complex, that is, not describable in all detail but definitely the concern of cybernetics as a living system.

The School had one evening of complete relaxation when 65 members went to the Shakespeare Memorial Theatre to see Miss Peggy Ashcroft in "As You Like It" — a memorable performance.

The Analogue Calculator

On Friday evening Mr. K. B. Haley, a research student under Dr. Dudley, brought the house down with a remarkable piece of apparatus, an Analogue Calculator for solving linear programming problems, and although it was purely mechanical it left the School almost as puzzled as they had been by Dr. Pennycuick's L.P. problem. Mr. J. Harling, of ORbit Ltd., concluded the programme by giving a Paper with case studies showing that Operational Research methods had been profitably applied to several industrial problems. In particular he dealt with: (1) control of stocks so as to ensure the best employment of working capital invested; (2) use of simulation techniques to secure the least cost balance between investment in facilities and waiting times; (3) use of programming methods to determine the most profitable course of action among many alternatives — emphasising throughout that the purpose of Operational Research problems was always a practical one, that of saving financial outlay, or by more efficient production methods.

The School dispersed early on Sunday morning feeling that, although certain doubts and difficulties still remain to be resolved, they had actively participated in a subject which, though comparatively new, appears to have endless and fruitful possibilities for assisting the production engineer in his prime aim of eliminating all sources of waste in material, skill and time.

F.W.C.

PERA NEWSLETTER — concluded from page 617

the determination of blank diameters for rolling unified screw threads, impact extrusion of steel, the effect of reamer shape and cutting conditions on the accuracy and surface finish of reamed holes in steel, the suitability for workshop use of the plastic replica method of surface finish measurement, and methods of de-burring machined components.

During the year, 155 practical investigations were also carried out for individual members into tool grinding and inspection, finish blanking, chip breaking, vibration in machine tools and other production plant, corrosion, tapping, metallurgical aspects of cutting tools and punches, drilling, etc.

The report also refers to the very heavy demands made on all the information and educational services, including the technical enquiry service, monthly Bulletin, library, mobile unit, five-day intensive courses, refresher courses for workshop personnel, etc.

Finance

Income for the year totalled £203,934, an increase of £44,645 over 1955. In 1956 the Association earned the maximum grant of £75,000. Council are pleased to report that the response by members to the modified subscription scale was very satisfactory, and the increased income will enable the Association to extend the facilities and services for the benefit of members.

In October, the Association's delegation led by Sir William Stanier, President of the Association, met the Industrial Grants Committee to discuss the Association's application for revenue grant for the period 1957 - 1961 inclusive. Following this meeting, the Department informed the Council that the terms of revenue grant for the next five years would be: £65,000 grant on the first £100,000 of industrial income, and £50 on each £100 of industrial income in excess of £100,000 up to a maximum additional grant of £25,000.

Membership

The total membership at the end of 1956 was approximately 500 firms. Industrial subscriptions increased from £79,000 in 1955, to £120,000 at the end of 1956, an increase of over 50%. Although the economic situation and trading conditions have affected the engineering industry during the past year, interest in PERA and its activities has continued to increase, resulting in a steady growth in membership.

Education and Training Department

All the educational activities of the Association have now been grouped into an Education and Training Department, and Mr. R. L. Hayward has been appointed Manager of the Department. A new series of intensive five-day courses on improved production techniques started in the new education and training centre on June 24th, and these are being attended by key production personnel from many industries.

Production Engineering Research Association of Great Britain

Quarterly Newsletter to the Institution

Twelfth Annual General Meeting

The 12th Annual General Meeting of the Association was held on Tuesday, 18th June, at Melton Mowbray, when Sir William Stanier, F.R.S., was re-elected President of the Association.

The following were newly-elected to PERA Council :-

Mr. F. V. Everard, Works Executive Director, Belliss & Morcom Ltd.

Mr. E. A. Hyde, Managing Director, Wickman Ltd.

Mr. J. Russell Lang, Director, G. & J. Weir Ltd.

Mr. F. P. Laurens, Managing Director, Powers-Samas Accounting Machines Ltd.

Mr. M. I. Prichard, Deputy Managing Director, F. Perkins Ltd. (previously co-opted).

The following retiring members of Council were re-elected :-

Mr. W. Armstrong, Director, Armstrong (Leeds) Ltd.

Mr. L. L. Bott, Works Director, Davey, Paxman & Co. Ltd.

Mr. J. O. Bowley, Director and General Manager, A.E.C. Ltd.

Mr. B. H. Dyson, General Manager, Overseas Production, Hoover Ltd.

Mr. J. B. S. Gabriel, Chairman, Charles Churchill & Co. Ltd.

Mr. J. W. Garton, Chairman and Managing Director, The Hoffman Manufacturing Co. Ltd.

Mr. E. W. Hancock, M.B.E., Director and General Manager, Humber Ltd.

Dr. H. Schofield, C.B.E., Chairman, J. A. Crabtree & Co. Ltd.

Mr. A. L. Stuchbery, Chief Technical Engineer, The Metal Box Co. Ltd.

The Chairman's Report stated that work on 32 general investigations was carried out during 1956 on press-working, machine tools, lubricants, thread rolling, cutting tools, de-burring, vibration, machinability of materials, work positioning and handling, surface finish, etc. Reports were issued on a number of researches, including investigations of tap accuracy and performance, drill performance and geometry,

(*concluded on foot of page* 616)

Part of the interior of PERA's new research block

news of members

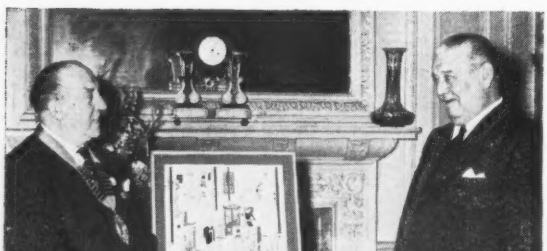
Mr. W. H. Bowman, Member, has been appointed to the Board of Directors of High Duty Alloys Ltd. For many years, Mr. Bowman has been a well-known figure in the non-ferrous metal industry. Prior to his new appointment, he was a Director of T. I. Aluminium Ltd., and was also a Director of the Aluminium Wire & Cable Co. Ltd. Mr. Bowman serves on the Council of the Institution as Chairman of the Wales Region.

Mr. William Core, Member, has recently been appointed Sales Director of Alfred Herbert Ltd. He is a Past President of the London Section.

Mr. G. Konried, Member, is now with S.B. Division, CERN, Geneve 23, Switzerland.

Mr. H. Vernon, Member, has been elected Chairman of the Association of Electrical Machinery Trades. Mr. Vernon, who was appointed a local director of Thos. W. Ward Ltd. in 1936, and a full director in 1938, is also on the boards of Fredk. Town & Sons Ltd., Thos. W. Ward (India) Private Ltd., the Deighton Motor Co., George Hassall Ltd..

HARROGATE CONFERENCE PRESENTATION



Mr. F. J. Slee *(right)*, Manager, Shell-Mex & B.P. Ltd., Lubricants Dept., presenting to Mr. E. W. Hancock, M.B.E., Immediate Past President of the Institution, the original of the well-known Peter Kneebone cartoon on "Automation in Industry". The presentation took place at the recent Harrogate Conference on "Automatic Production — Change and Control". The cartoon may now be seen at the Institution's headquarters.

Marshall Sons & Co., and is chairman of management committees of Woodhouse and Mitchell, the Silent Machine and Engineering Co. and George Cooper and Sons.

Mr. G. A. Cleary, Associate Member, was recently appointed to the Board of Messrs. Longclose Engineering Co. Ltd., of Leeds, where he has for the past 10 years been Works Manager.

Mr. R. A. Cox, Associate Member, has recently been appointed a Director of Thomas Haddon & Stokes Ltd., Birmingham. He will continue to occupy the position of Works Manager.

Mr. D. L. Davies, Associate Member, has been appointed Chief Engineer of The London Hospital, Whitechapel, London, E.1.

Mr. J. A. Freel, Associate Member, has relinquished his position as Chief Estimator with E.M.I. Electronics Ltd.

Mr. T. Farrar, Member, has been appointed Works Director of Messrs. J. B. Brooks & Co. Ltd., Birmingham, and has also been made a Director of Messrs. Antler Ltd., a subsidiary of the Brooks Group of Companies. Mr. Farrar joined the Company in 1946 as Deputy Works Manager, was appointed Works Manager in 1948 and General Works Manager in 1950.

Major D. C. Gershon, Associate Member, is now officer in charge of planning and production control at 23 Base Workshop, R.E.M.E., B.F.P.O.20.

Mr. E. Hoyle, Associate Member, is now with Rhodesia Railways as a Work Study Engineer, and will be on leave in the United Kingdom during September and October, when he hopes to renew old acquaintanceships.

Mr. B. J. Howell, Associate Member, has relinquished his directorship of Production-Engineering Ltd., to join Tillotson & Son Ltd., as Development Director.

Mr. W. L. Johnson, Associate Member, will shortly be emigrating to Canada to take up a position with Avro Ltd., Malton, Ontario, as a Designer.

Mr. G. L. Lewis, Associate Member, has joined Messrs. Grindwell Abrasives Ltd., Bombay, as their Technical Sales Manager.

Mr. I. M. Quilter, Associate Member, has now joined the staff of C. W. F. Hamilton & Co. Ltd., Christchurch, New Zealand.

(continued opposite)

Hazleton Memorial Library

REVIEWS & ADDITIONS

REVIEWS

"Designing for Production" by Edward N. Baldwin and Benjamin Niebel. *Homewood, Illinois, Richard D. Irwin Inc.*, 1957. 645 *pages. Diagrams.*

This book provides a convenient work of reference for the draughtsman and design engineer. The authors have managed to condense a considerable amount of information into a relatively small space. The contents comprise information similar to that gathered in note form by practising engineers over their working careers, and because of its breadth, the book suffers in lack of detail.

For a book on design the very language of which is drawing, some of the engineering drawings are rather poorly presented, although this defect is balanced by the clarity of the type of illustrations used in Chapter 8, showing the difference between desirable and undesirable design forms.

The tabular form of presentation used for material comparisons is very useful and obviates a lot of searching for particular points of information. It is unfortunate that the specifications used are American, and this detracts from the book's value in the United Kingdom. Perhaps the next time a similar volume is published the authors will remember the needs of those who work to British Standard Specifications and include B.S. equivalents wherever possible.

The practice of putting test questions at the end of each chapter is useful in assisting the reader to realise how much of his reading has really been absorbed.

Chapters 1 to 3 of this book present the position of the product designer in relation to the production, sales, and economic function, and help to create the sense of perspective so often lacking in person restricted to one discipline. The succeeding chapters on materials and processes are up-to-date and contain much that will be of use to the student and practising designer. It is a pity that a bibliography has not been included with each section, as this would materially enlarge the value of the book as a work of reference. Chapter 22 on packaging fills a gap that is often neglected and left much to chance. Chapter 23, dealing as it does with such an eclectic subject as automation in 10 pages, would perhaps have been much better omitted.

The general layout of the book is pleasing and the quality of the paper and binding good, making it a pleasing volume to handle. J.I.

"Management in Action: the Art of Getting Things Done Through People" by Lawrence A. Appley. *New York, American Management Association,* 1956. 382 *pages.* £2.

This book, as it noted in its early pages, is based upon the author's writings in various publications of the American Management Association. It is also very obviously based upon his wide experience of life. The author has lived, observed and noted the motivating forces that affect every action; in putting the results of these observations on paper and making them available for scrutiny, the author and the American Management Association have performed a public service. For this book, as Lillian M. Gilbreth observes in the foreword, is more than a management treatise: it is a philosophy of life. Anyone having read this book who feels he is living up to half its dictums is indeed serving a useful life, and must be a "good manager" in the widest sense of the phrase.

Much emphasis is placed upon the oft-forgotten fact that the most precious asset of any organisation is a keen and happy staff, and that management's prime function is to achieve and maintain this mood.

Reviewing this book is a difficult task, for it is very like trying to review life itself. Because of its broad face, the book must contain much that one disagrees with, but it can truthfully be said that anyone who reads and absorbs it, whatever his views, will benefit in some measure. The book is primarily written for the American market and indulges needlessly in the current practice of tilting at Communism.

Part 2 is worthy of wide reproduction in order that busy personnel, already swamped by the increasing flood of literature. can be given the opportunity of absorbing the fundamentals of the work so neatly summarised therein.

It is felt that if managers and employees acted upon the philosophy expounded in this volume both their working career and personal life would be more satisfying and the world would be a better place to live in; no book can hope to achieve more.

The format is pleasing, the print easy to read, and the book well bound. It is unfortunate that as an American publication it falls into the category of the higher priced books that people tend to borrow from the library rather than buy for a well-earned place in a private bookshelf. J.I.

ADDITIONS

American Society for Engineering Education. **"Report on Evaluation of Engineering Education, 1952 - 1955."** 1955. 36 *pages. Obtainable from the Secretary, American Society for Engineering Education, University of Illinois, Urbana, Illinois, U.S.A.* 25 cents.

The Committee studied engineering education in the U.S.A. It was asked to recommend "the pattern or patterns that engineering education should take in order to keep pace with rapid developments in science and

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Mr. T. C. Winmill, Associate Member, has relinquished his position as Head of Organisation and Methods Division with Cox & Co. (Watford) Ltd., and has taken up an appointment with Stein Atkinson Vickers Hydraulics Ltd., as Production Engineer.

Mr. A. J. Lawrance, Graduate, has been appointed Works Director of Kimber-Allen Ltd., Lewisham, a Company newly-formed to carry on the combined activities of Batco Tools Ltd.

Mr. A. G. Smith, Associate Member, is now a Plant and Production Engineer with The Western Bridge and Steel Fabricators, Vancouver, Canada.

Mr. E. W. Stobart, Graduate, has taken up an appointment with The Northern Electric Co. Ltd., Montreal, in the manufacturing engineering and works service department, of the Wire and Cable Division.

technology, and to educate men who will be competent to serve the needs of, and to provide the leadership for the engineering profession over the next quarter century". The Committee was asked to give special consideration to the development of standards and to clarify the curriculum content "that differentiates engineering education from that in science on the one hand, or in sub-professional technology on the other". Amongst the Committee's recommendations are: the strengthening of work in the basic sciences, including mathematics, physics and chemistry; the identification and inclusion in curricula of six basic engineering sciences which should be the common core of engineering courses (e.g. mechanics of solids; electrical theory); the inclusion of optional subjects; the encouragement of experiment; insistence on a high standard of performance in the oral, written and graphic presentation of facts and ideas; the strengthening of post-graduate courses; a high standard of teaching; some formal study of the humanities and social sciences. The Committee was helped by engineering colleges and industrial concerns. Its preliminary report was published in 1953, and its Interim Report in 1954.

American Society of Mechanical Engineers, New York. **"Mechanical Catalogue."** *New York, the Society,* 1956. 694 *pages. Illustrated.* Free to members of the A.S.M.E. Includes a classfied guide to American manufacturers and a complete list of A.S.M.E. publications.

Aston, R. L. **"The Diesel Locomotive."** *London, Thames and Hudson,* 1957. 116 *pages. Illustrated. Diagrams.* 12s. 6d.
A brief historical introduction, and accounts of the basic principles of the diesel locomotive, is followed by accounts of the fuel injection system; electrical, mechanical and hydraulic systems of transmission, and auxiliary equipment. There are chapters on safety measures, planned maintenance, and on operating faults and adjustments. The book is inspired by a series of lectures given by the author to footplate and maintenance workers of British Railways.

Beer, Stafford. **"The Scope of Operational Research in Industry."** *London, Institution of Production Engineers,* 1957. 23 *pages.* 10s. (George Bray Memorial Lecture, 1956.)
The author is Head of the Department of Operational Research and Cybernetics of the United Steel Companies. In this Paper he surveys the field for the industrial application of operational research, and explains some of the principles involved.

British Engineers' Association. **"Classified Handbook of Members and their Manufactures."** *London, the Association,* 1957. 680 *pages.* 21s.

Carter, C. F. and Williams, B. R. **"Industry and Technical Progress: Factors Governing the Speed of Application of Science."** *London, Oxford University Press,* 1957. 25s.

Cherry, J. **"Machinability Dynamometers Used at the College of Aeronautics."** *Cranfield, College of Aeronautics,* 1955. 27 *pages.* (CoA Note 34.)

"His Royal Highness the Duke of Edinburgh's Study Conference on the Human Problems of Industrial Communities within the Commonwealth and Empire." *Oxford,* 1956. *London, Oxford University Press,* 1957. 2 *volumes. Illustrated.* 42s.
Members of the Conference were drawn from all levels of industry from all parts of the Commonwealth and Empire. They discussed the impact of industrialisation upon the older industrial countries, and upon such communities as those of East, West and South Africa, India, and the West Indies. Volume 1 contains a foreword by H.R.H. Prince Philip, introductory chapters by Sir Harold Hartley, Sir Reginald Verdon Smith, Sir Alexander Fleck and Sir Thomas Williamson, together with all the addresses, the summing-up by Sir Philip Morris, and the reports of the 20 study groups which were the working units of the Conference. Volume 2 contains the 25 background Papers contributed by writers in the United Kingdom and the Commonwealth, together with notes on the internal organisation of the Conference.

Hanover. Technische Hochschule. **"Festschrift zur 125. Jahrfreier der Technischen Hochschule Hanover: 1831 - 1956."** *Hanover, the School,* 1956. 278 *pages. Illustrated.*
Published to celebrate the 125th anniversary of the foundation of the Technische Hochschule, Hanover. Includes a short account of the evolution of the technical education system in Germany, and of the Hanover School in particular. Reviews the work of the School at the present day.

Hooper, Dudley W. **"Mechanisation Present and Future."** *London, Incorporated Accountants' Research Committee,* 1954. 40 *pages.* 5s.
A review of mechanised accounting, which includes a description of the basic composition of an electronic computer, and a summary of the historical development of calculating and computing devices.

International Labour Office. 40th Session, Geneva, 1957. **Report of the Director General. Part I—"Automation and other Technological Developments: Labour and Social Implications."** *Geneva, The Office,* 1957. 105 *pages.* 6s.
Recent progress with automation and atomic energy; the pace of progress; the impact on employment; social changes; education and training; planning technological change within undertakings; dismissal and re-employment; labour mobility; wages and hours of work; safety and health; job satisfaction; social security needs; management and labour; Government services.

Junior Institution of Engineers. **"Journal and Record of Transactions."** Volume 66, 75th Session, 1955 - 1956. *London, the Institution,* 1956. 448 *pages.*

Loughborough College. Past Students' Association. **"The History of Loughborough College, 1915 - 1952."** *Loughborough, the Association,* 1957. 172 *pages. Illustrated. Portraits.*

Organisation for European Economic Co-operation, Paris. European Productivity Agency. **"Internal Transport in Iron and Steel Works."** *Paris, the Agency,* 1956. 216 *pages. Plates.* 7s.
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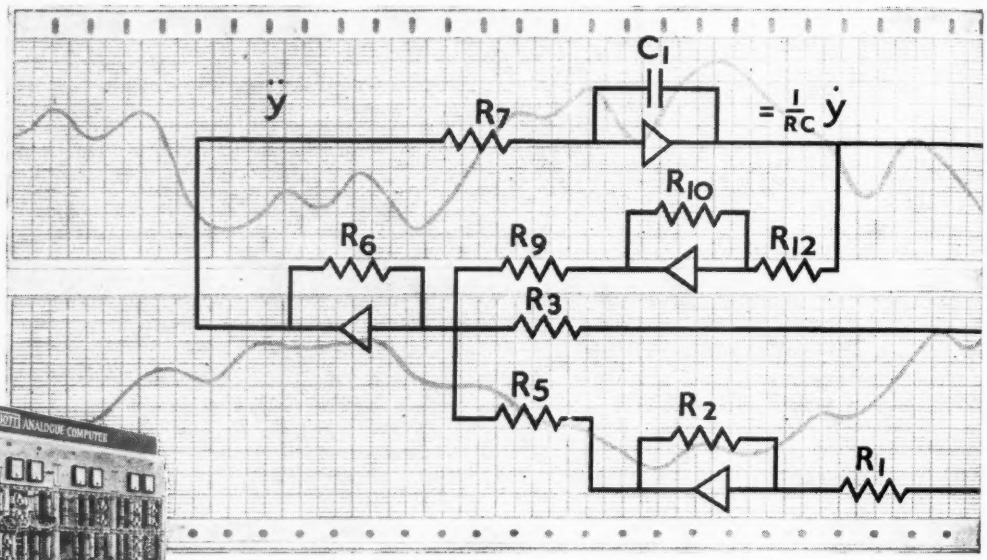

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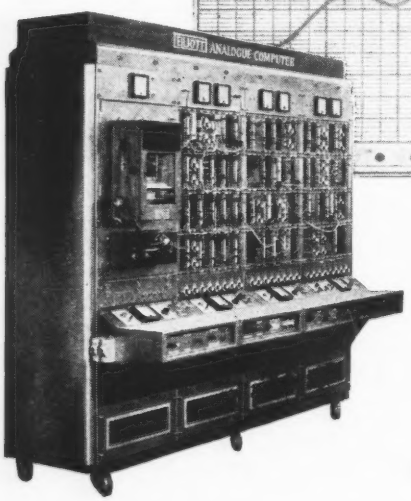

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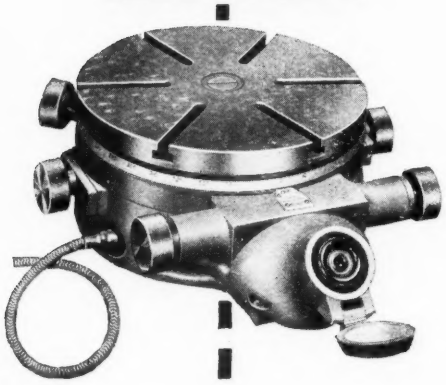

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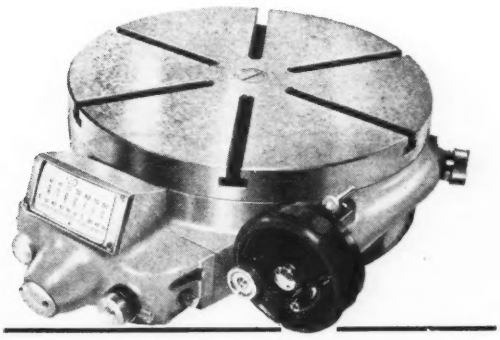

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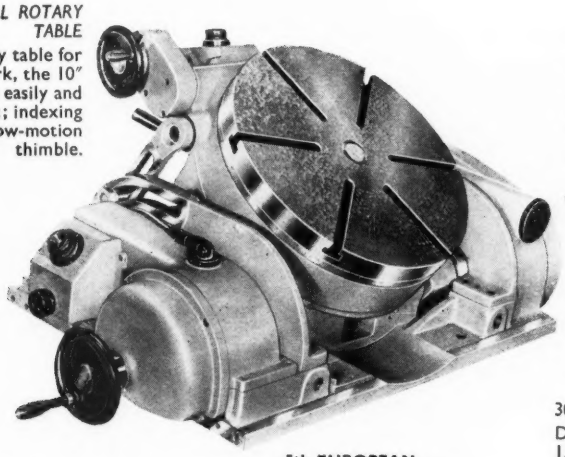

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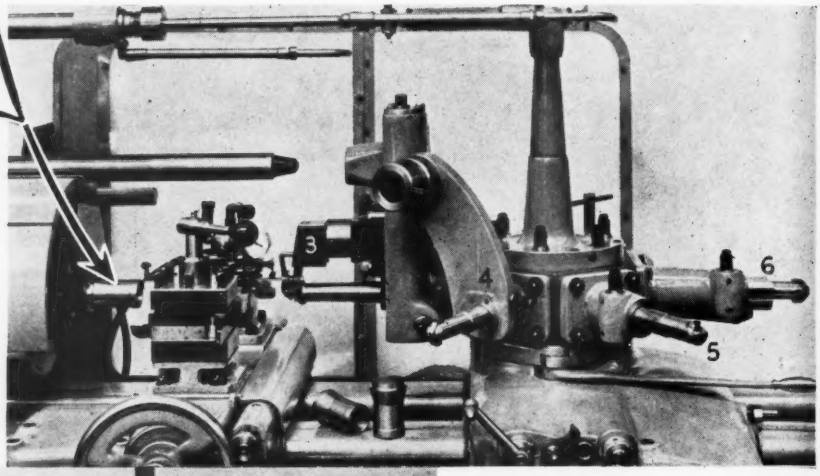

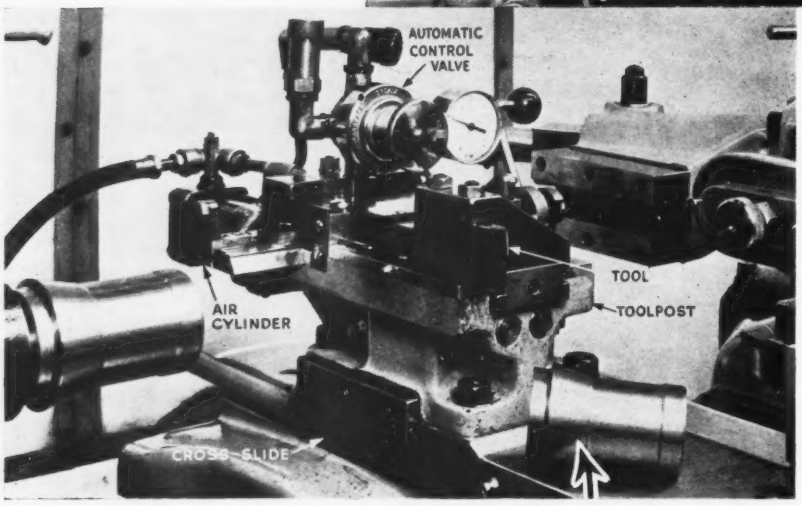

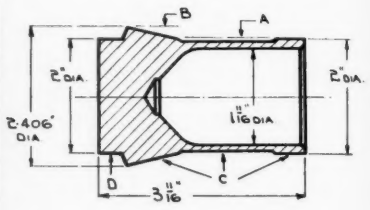

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DESCRIPTION OF OPERATION	Tool Position		Spindle Speed R.P.M.	Surface Speed Ft. per Min.	Feed Cuts per inch
	Hex. Turret	Cross-slide			
1. Feed to Stop and Start Drill	1	—	350	—	Hand
2. Support and Rough Form Taper	2	Front 1	100	66	Hand
Rough Form Head	—	Front 2	100	66	Hand
Drill and Rough Knee Turn 2" dia.	3	—	200	161	266
4. Finish Turn and Face D	—	Front 3	700	440	Hand
5. Profile Turn C (Copy Attachment)	6	Rear	700	440	186
6. Rough Bore Bottom	4	—	170	75	Hand
7. Microbore 1 11/16" dia.	5	—	1000	442	266
8. Finish Bore Bottom, Face and Chamfer	6	—	70	30	Hand
9. Part Off	—	Front 4	240	126	Hand

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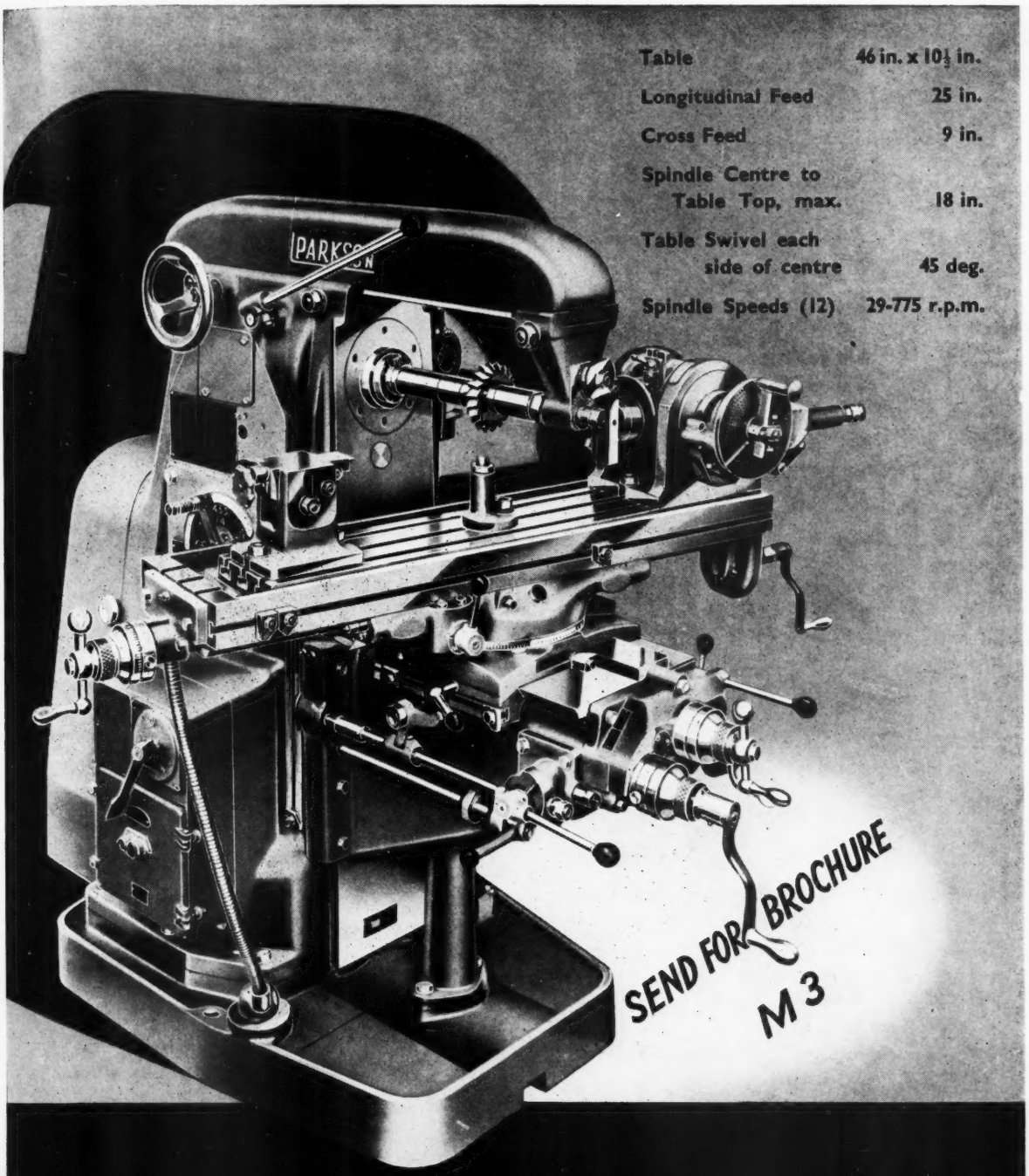
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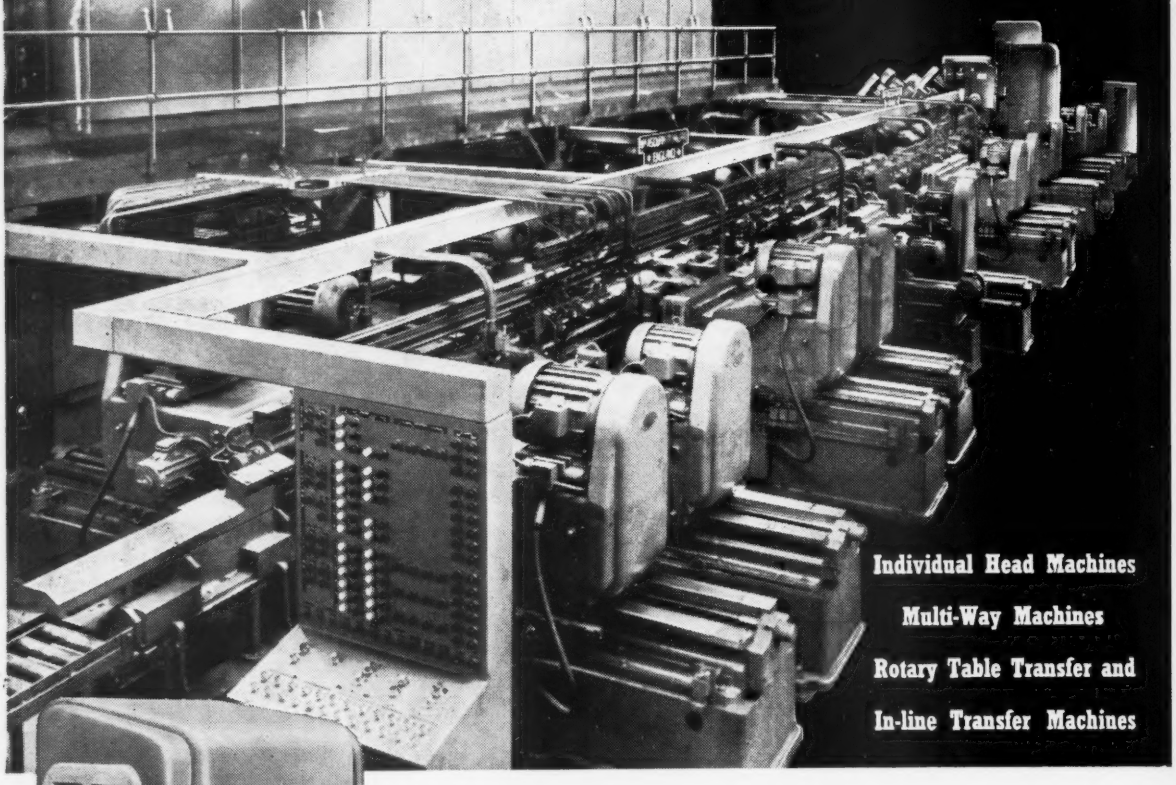

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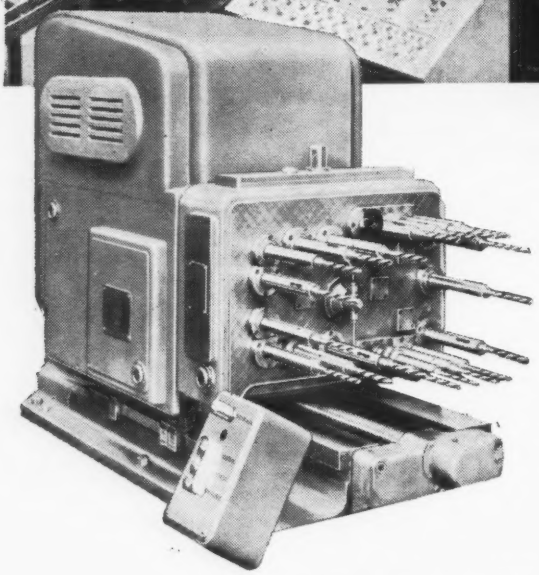

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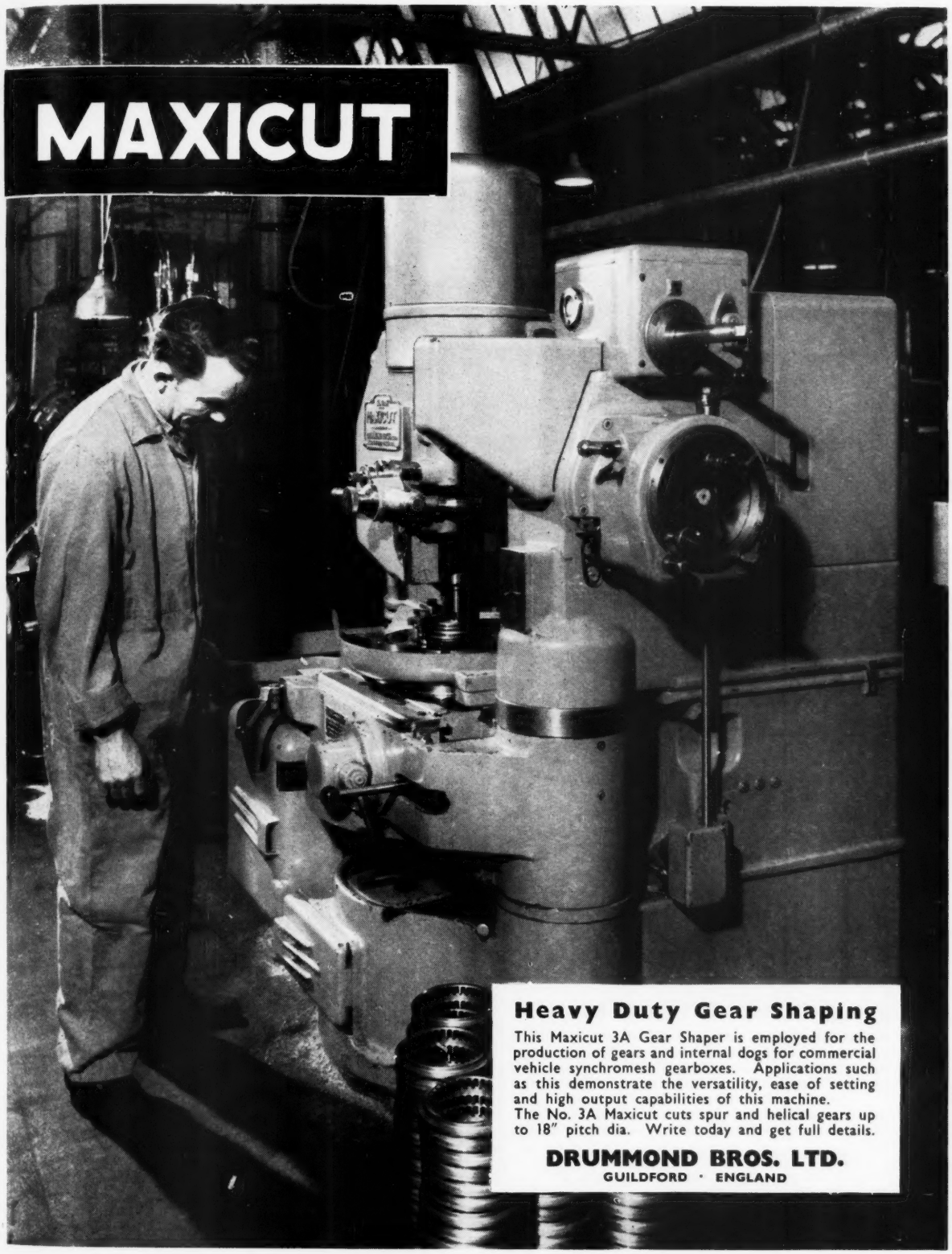

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D.217

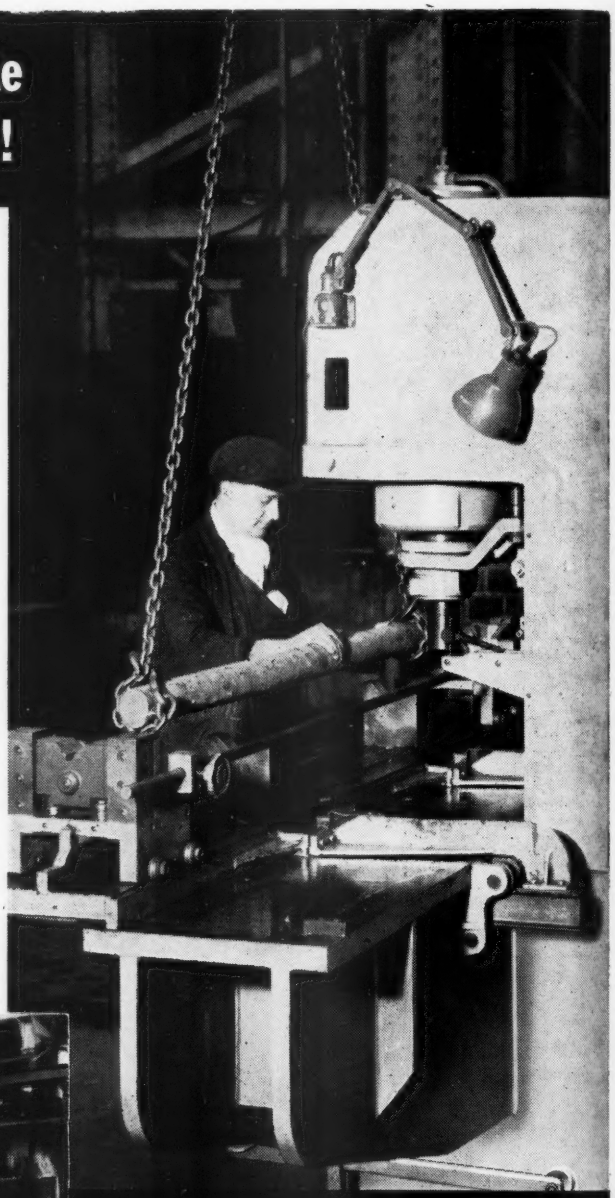
Load and unload outside the throat of the Press!

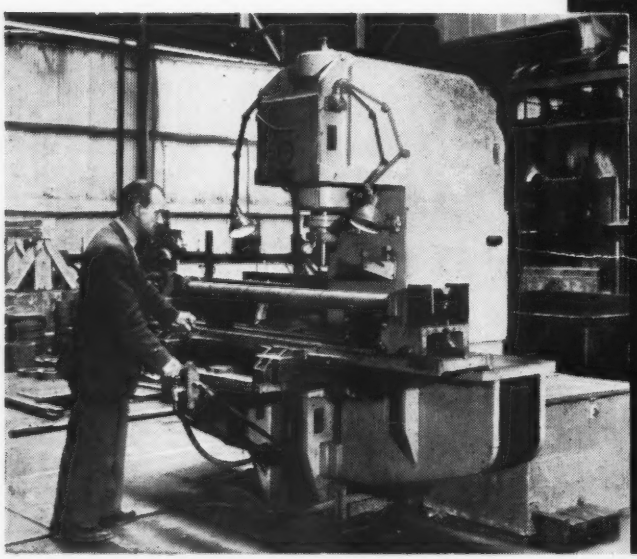
This 75-ton Hi-Ton Straightening Press incorporates a hydraulic traversing table for loading and unloading outside the throat area of the machine.

The illustration opposite shows the table in its forward position, and loading is simplified and speeded up with a minimised risk of damage to the machine by heavy bars and lifting tackle.

The lower illustration shows a bar in position ready for straightening and the operator is depressing the lever to actuate the hydraulic return of the table to its rear position with the component beneath the ram.

Write today for details of this type of Straightening Press and mention the capacity which interests you.





HI-TON

STRAIGHTENING PRESS

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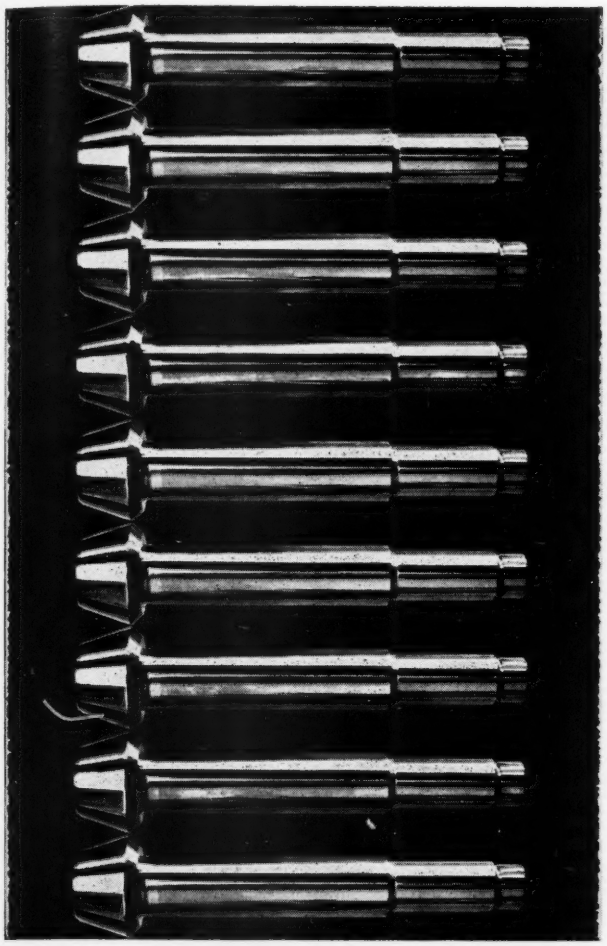


+GF+ Fully automatic Copying Lathes

Automatic programme:

Loading and unloading
Spindle actuation
Multi-cut cycle
Automatic diameter control

Setting up and changeover remains quick and easy.

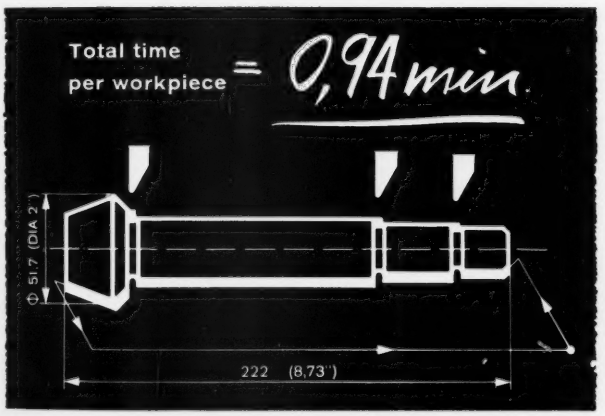
The programme may be cut into at any time.

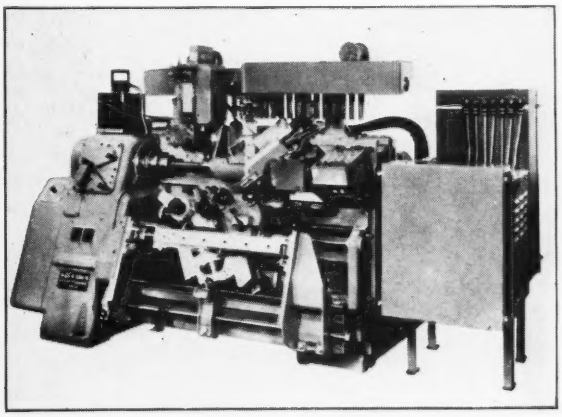
No rejects.

Two or more machines may be coupled together to form a fully automatic group.

One man can attend to several machines or groups of machines.

Every motion may be preselected individually, thus also permitting operation of the machine by hand.





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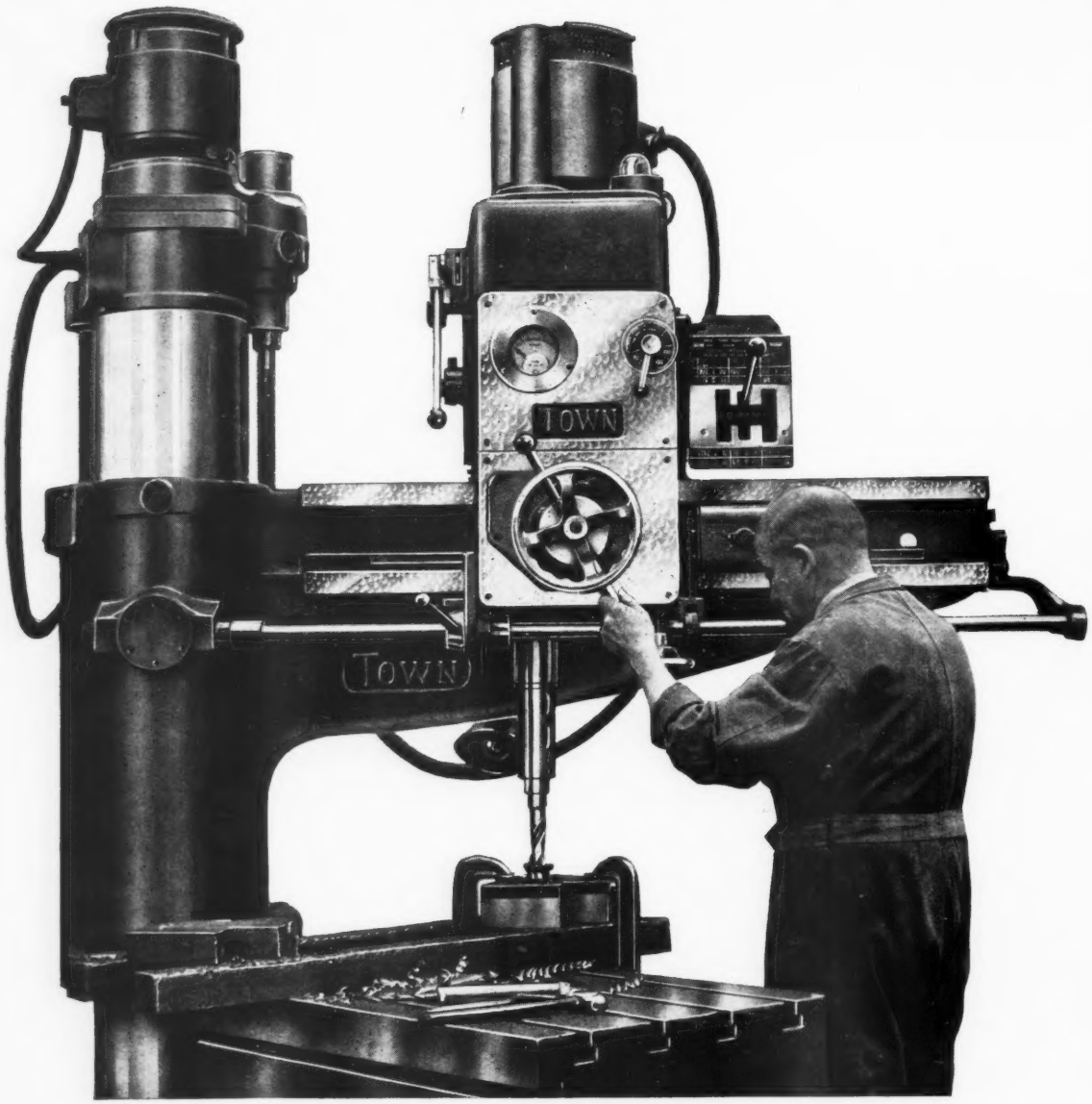

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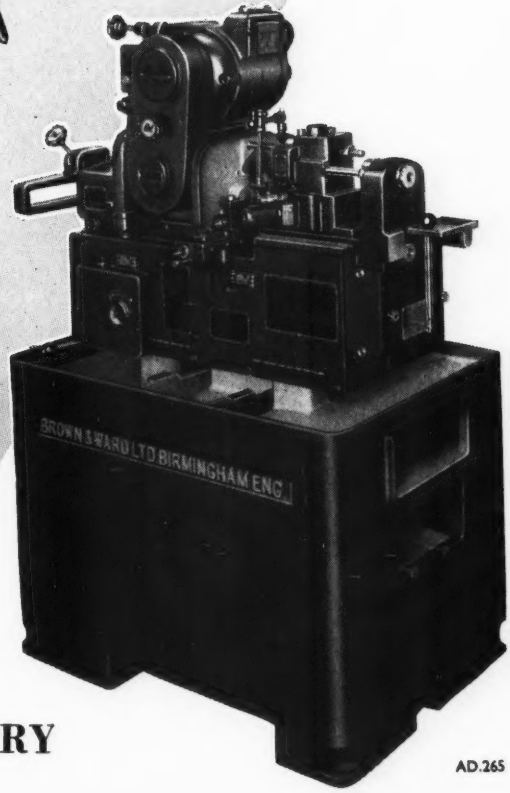
ESTABLISHED 1903

. . . . *production on* BROWN & WARD *bar automatics*



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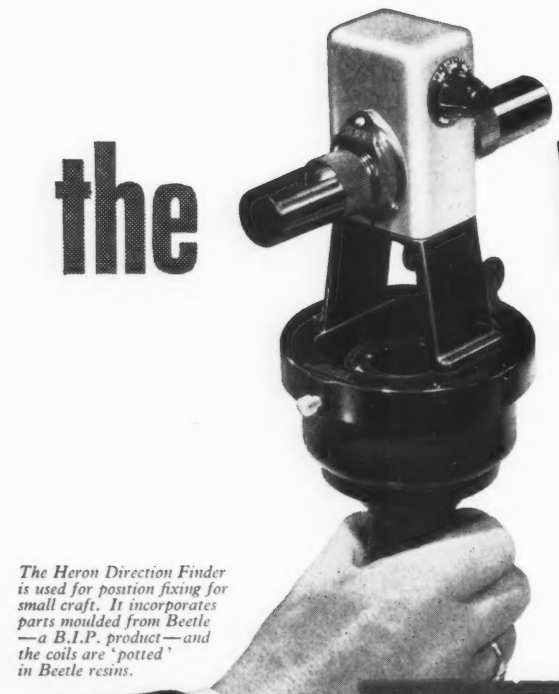

The Heron Direction Finder is used for position fixing for small craft. It incorporates parts moulded from Beetle—a B.I.P. product—and the coils are 'potted' in Beetle resins.

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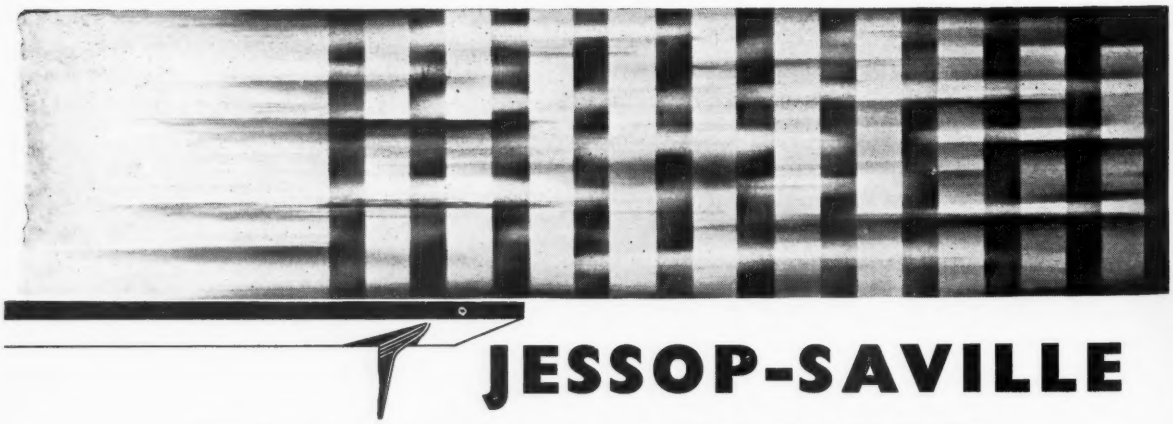

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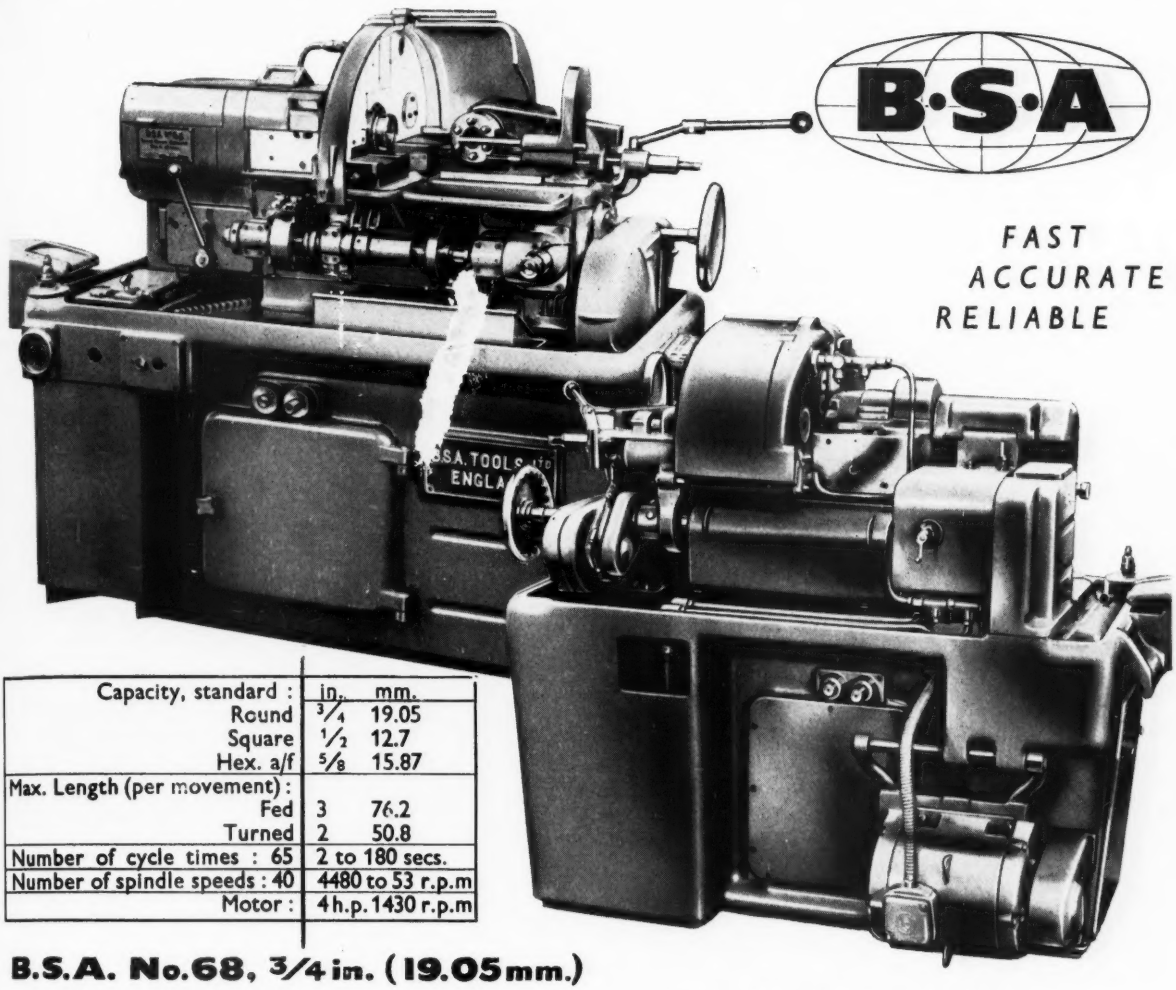

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Square	1/2	12.7
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Max. Length (per movement) :		
Fed	3	76.2
Turned	2	50.8
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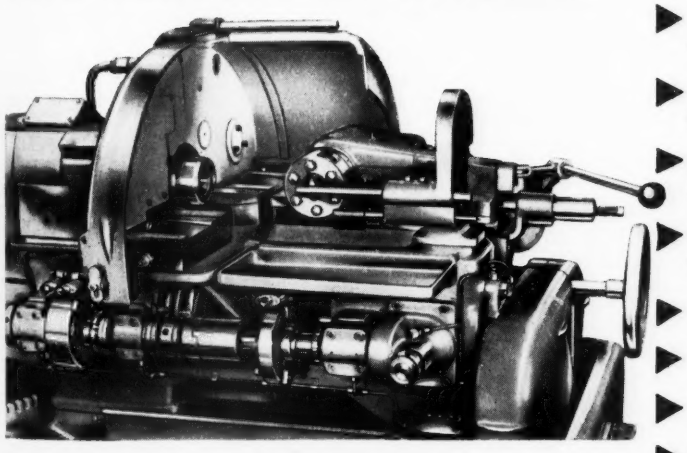

- All the latest developments for high-speed production to close limits of accuracy.
- Designed for ease of operation and simple and rapid change- over.
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- The spindle is driven smoothly and positively by chains.
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- Built to withstand constant high-speed operation.

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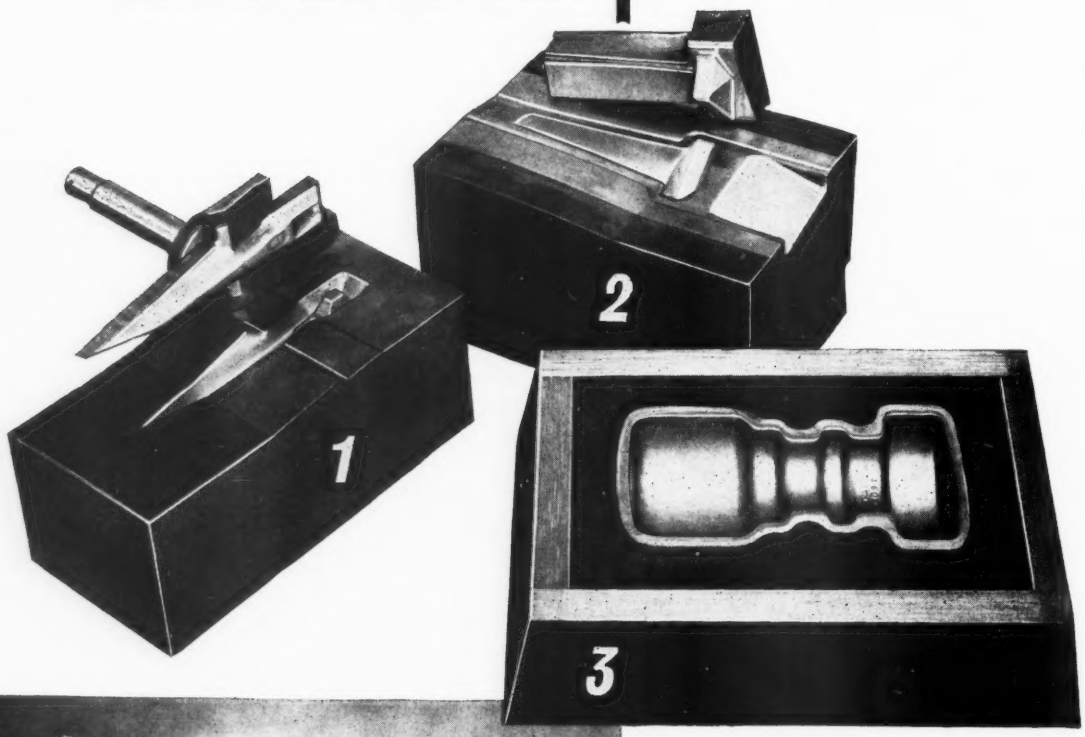

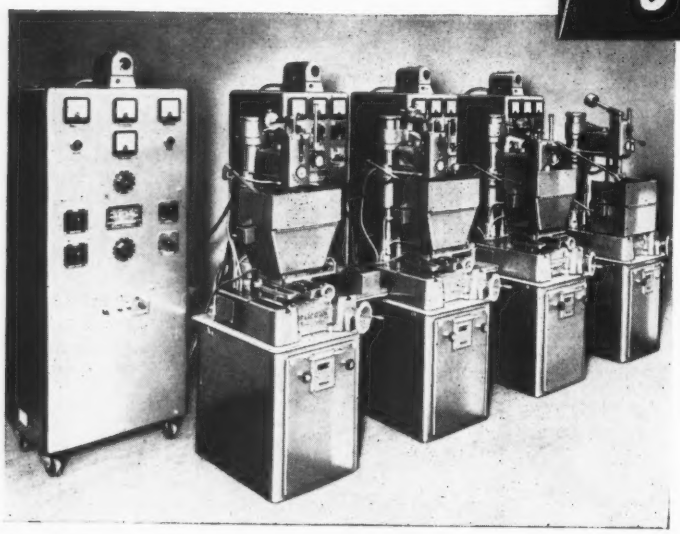

A battery of four Sparcatron heads operated from one main control unit in conjunction with three auxiliary control units.

1 Harvester Tine forging die machined from the solid by Spark Machining in the hardened state

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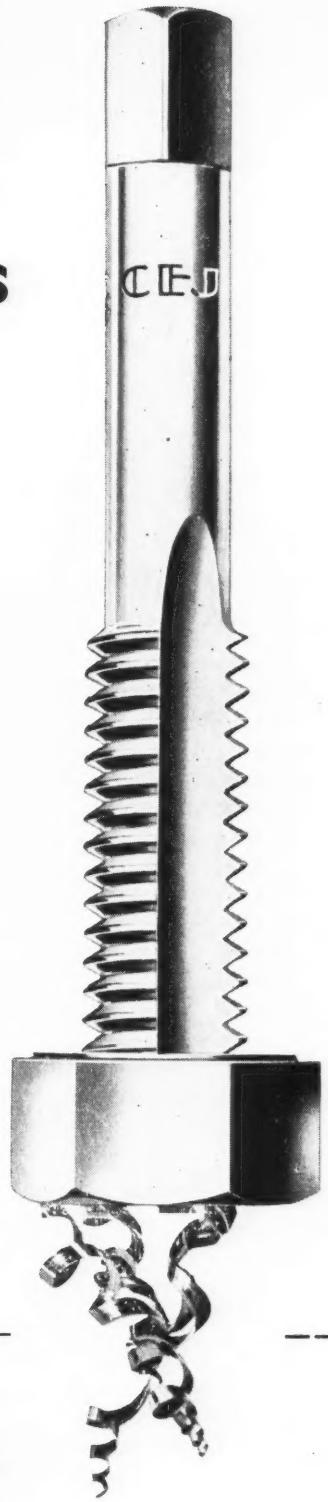
CEJ

THREADING TOOLS



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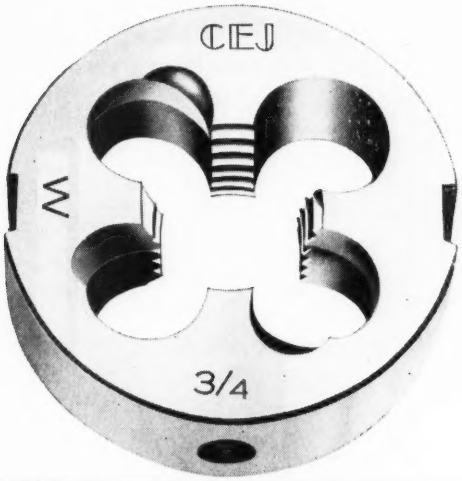

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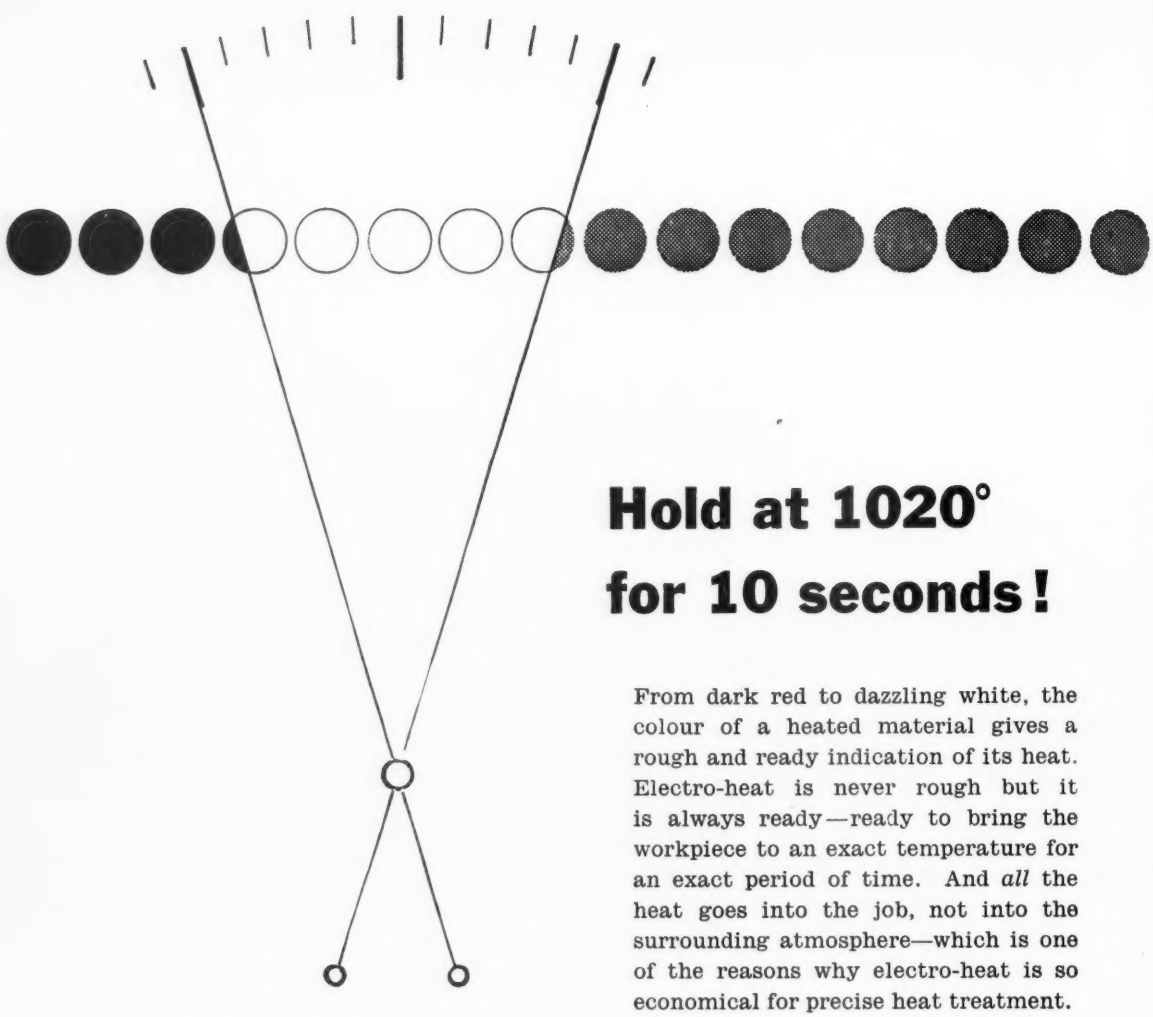

Hold at 1020° for 10 seconds!

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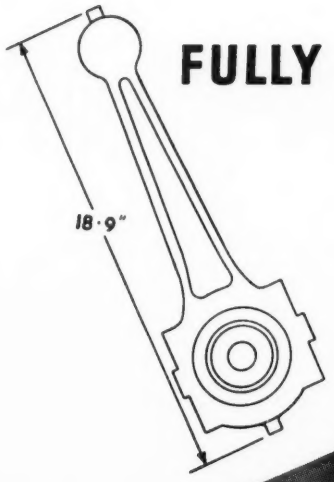

FULLY AUTOMATIC DIE SINKING IN 3-D

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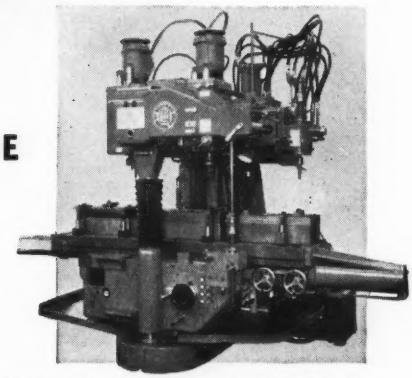

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NEVEN

There are no better diamond tools than those manufactured by Impregnated Diamond Products Limited of Gloucester.

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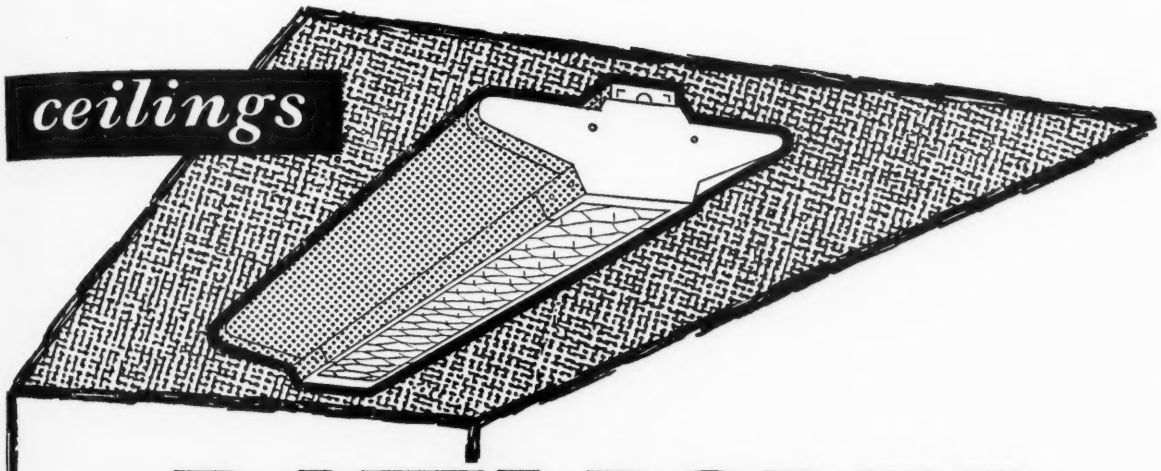

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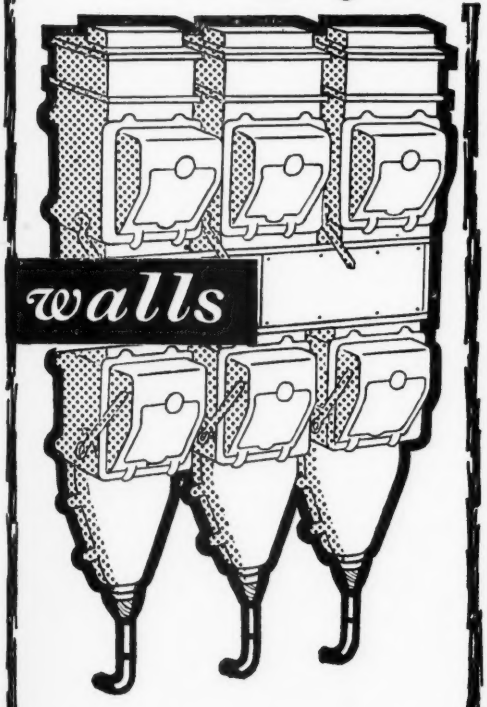
For heavy fixing to Ceilings, Walls & Floors



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Older methods of fixing involve laborious chiselling of holes, grouting in and waiting several days for cement to harden. With Rawlbolts, the job is far simpler and quicker. Drill a hole, insert a Rawlbolt and tighten up. Your equipment is fixed and ready for use immediately.

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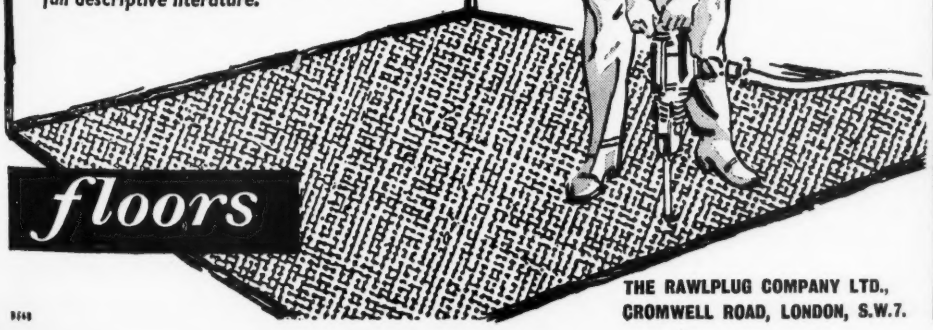
For more information, please write for Dimensional Chart of the Rawlbolt Range and full descriptive literature.



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Enots

AIR SERVICE UNITS
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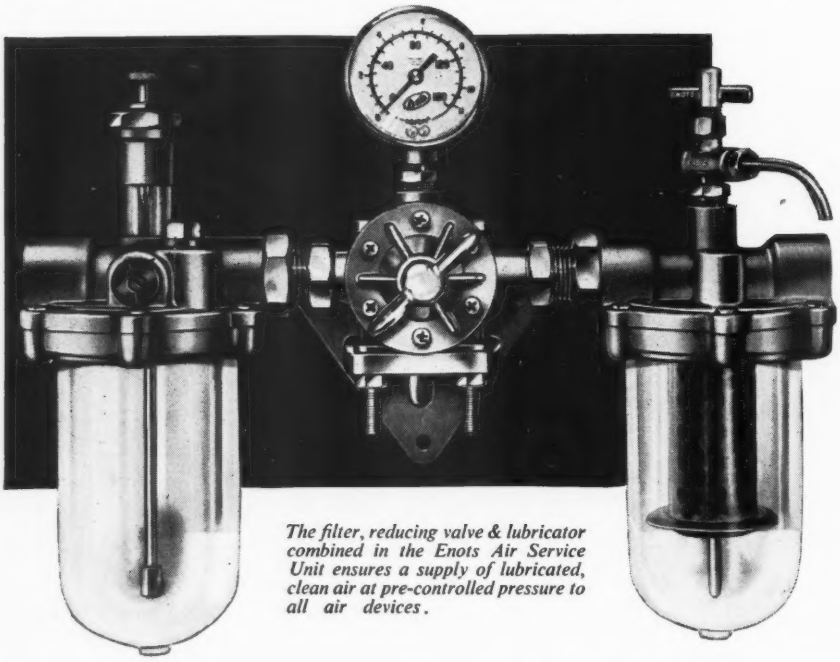
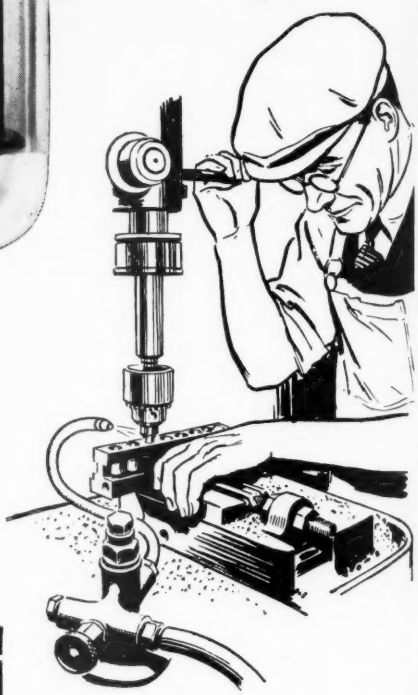
improve efficiency and reduce production costs



The filter, reducing valve & lubricator combined in the Enots Air Service Unit ensures a supply of lubricated, clean air at pre-controlled pressure to all air devices.

This man is saving money

He is in fact, saving as much as 90% in compressed air consumption by using an ENOTS PUFFER VALVE in place of an open ended pipe for the displacement of swarf. A leak in a 100 lb. per sq. inch air line, equivalent to a $\frac{1}{16}$" diameter hole will pass 390 cu. ft. of free air per hour and waste the equivalent of 2 tons of coal per year (2,500 hours operation).



A pressure reducing valve fitted to almost any pneumatic device will save its cost in a very short time by reducing air consumption. At how many points in your works are you using full line pressures of up to 100 lb. per sq. inch where 80, 60 or even lower pressures would be adequate? Savings are more or less in direct proportion to pressure reduction.

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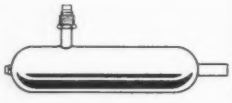

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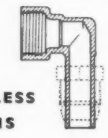

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B T-H

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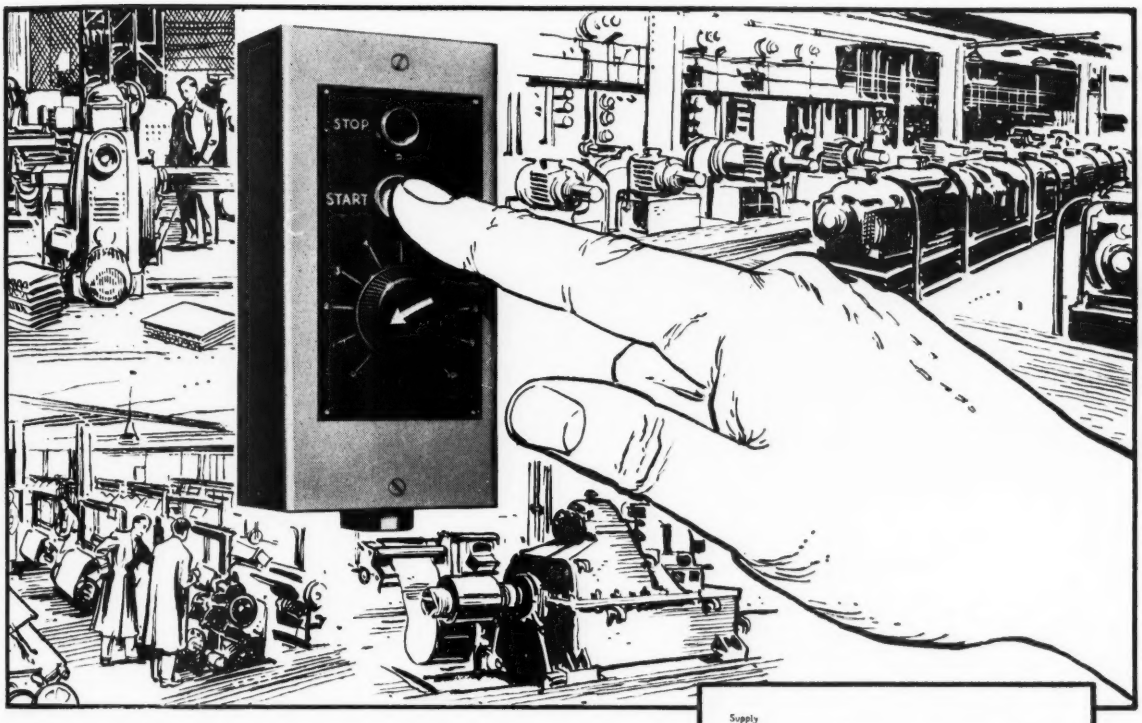
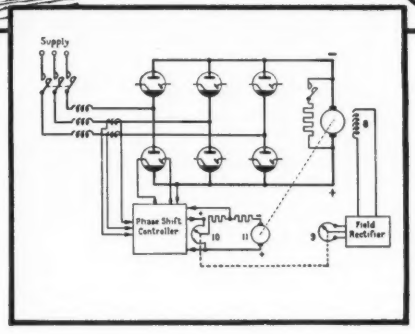
means | increased output
improved product
economy in operation





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BTH "EMOTROL" HAS THESE CLEAR ADVANTAGES

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- *Available in a wide h.p. range—¼ to 600 h.p.*
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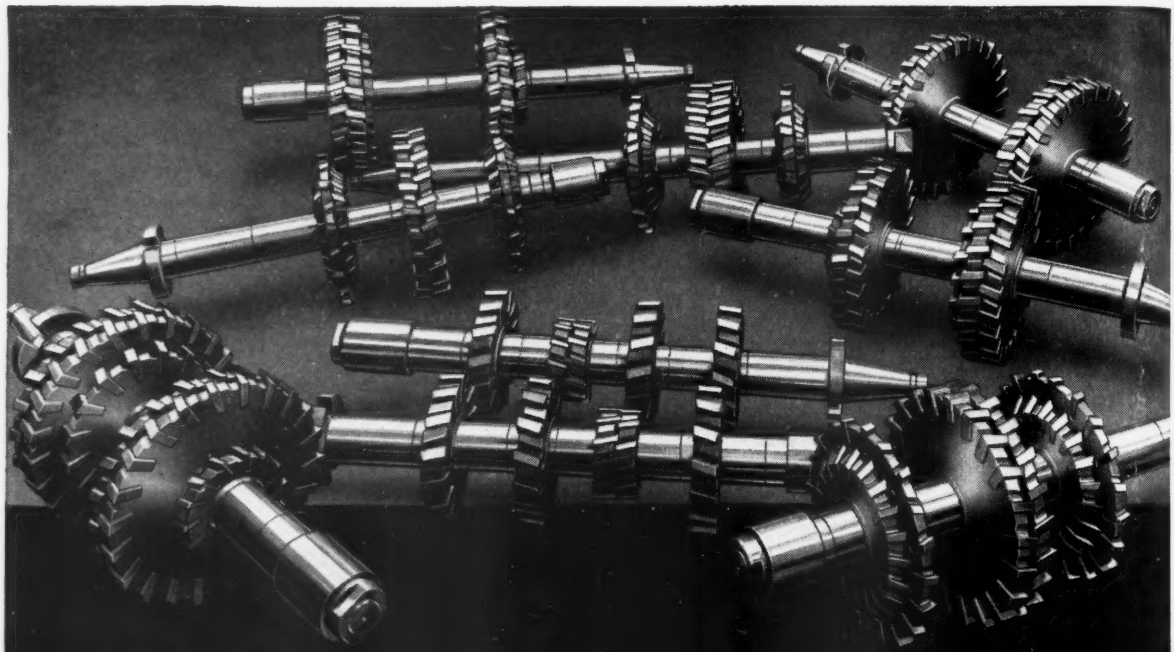
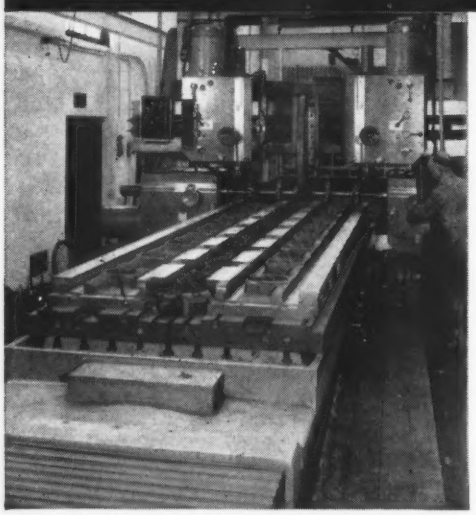


Multi-cutting speeds production —



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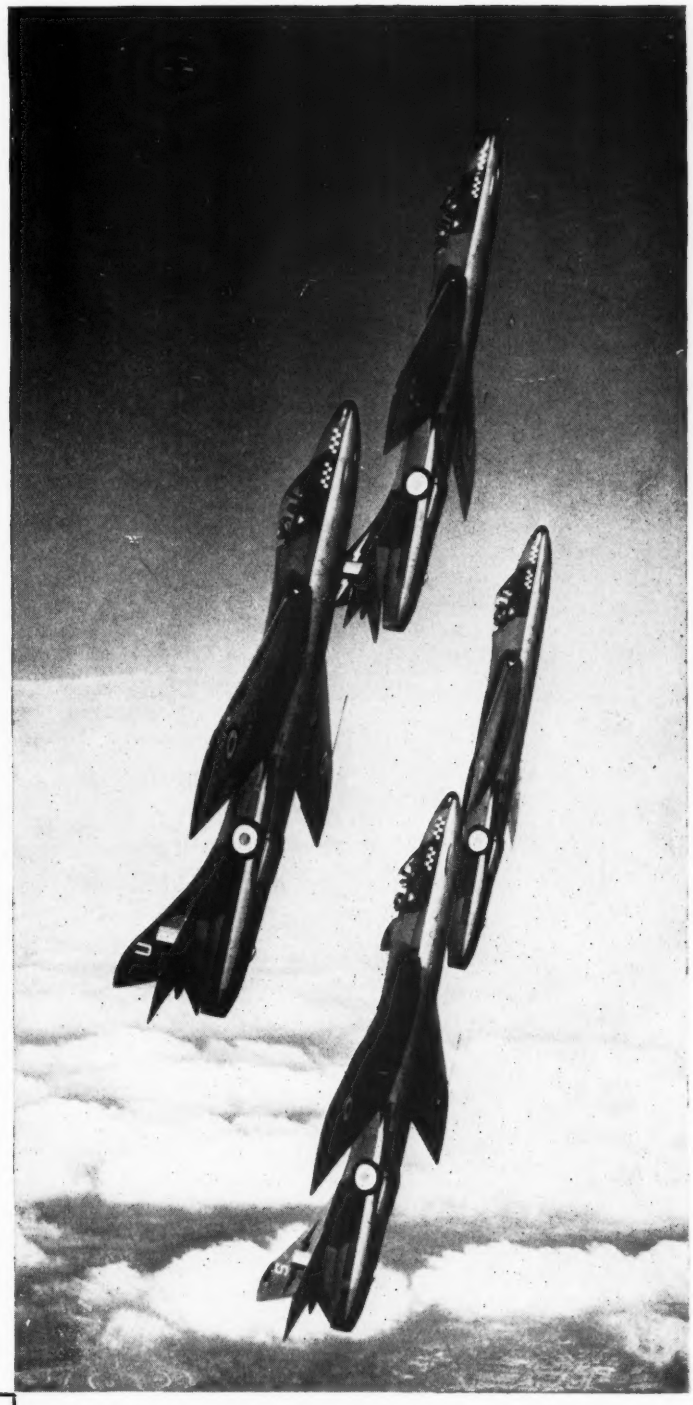

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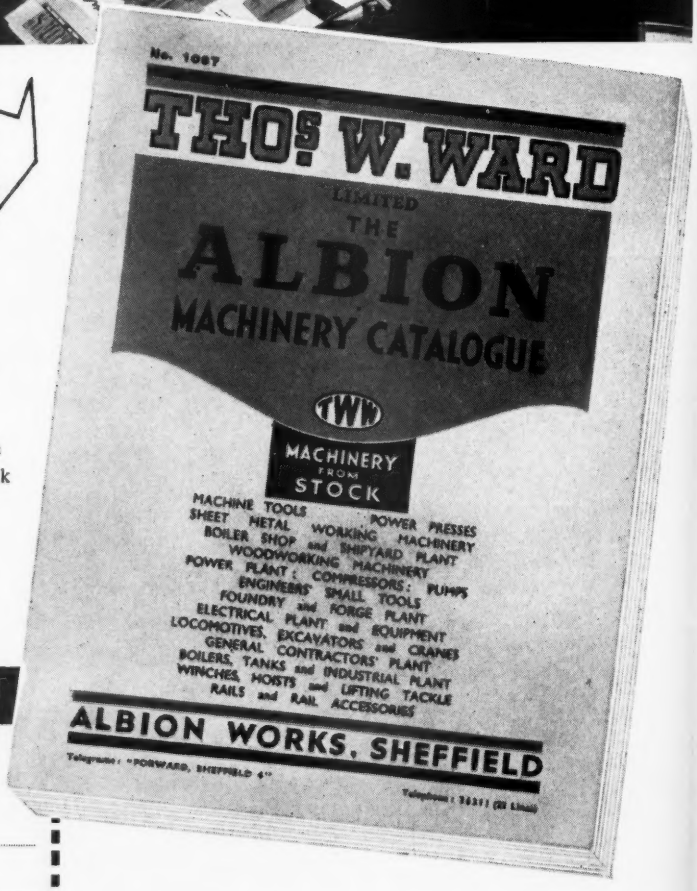

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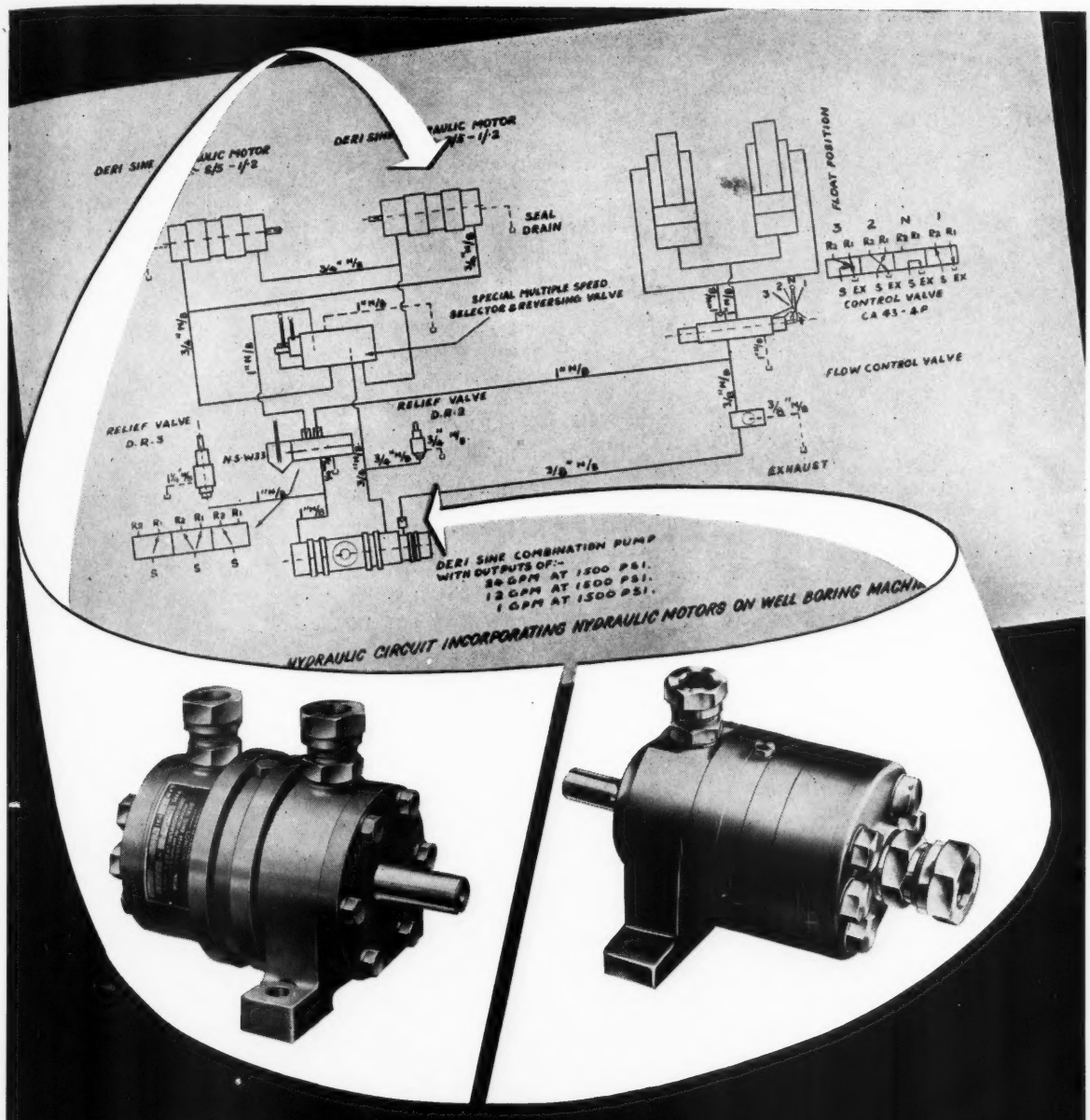

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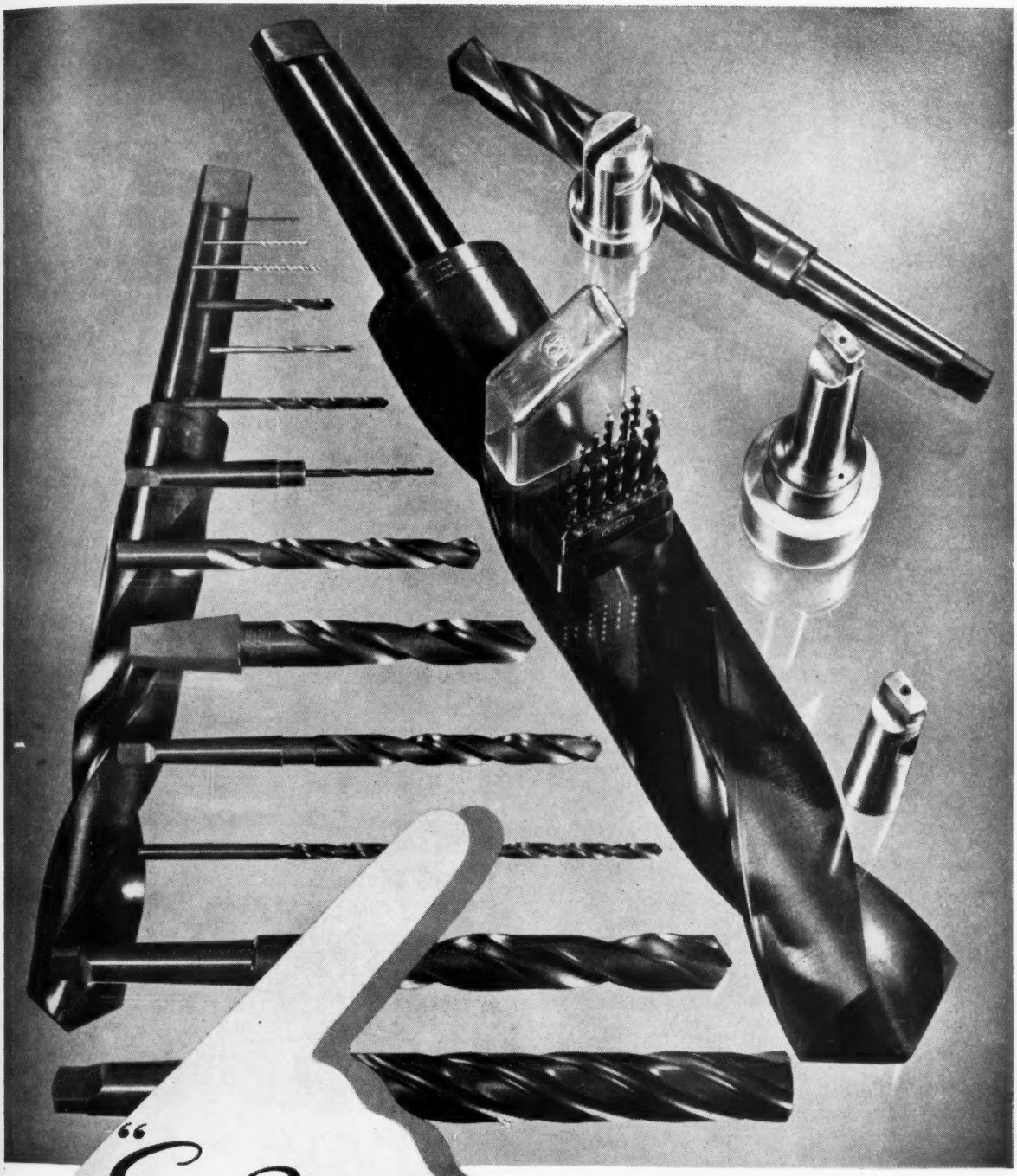

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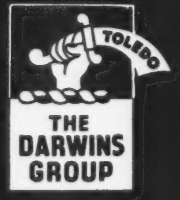

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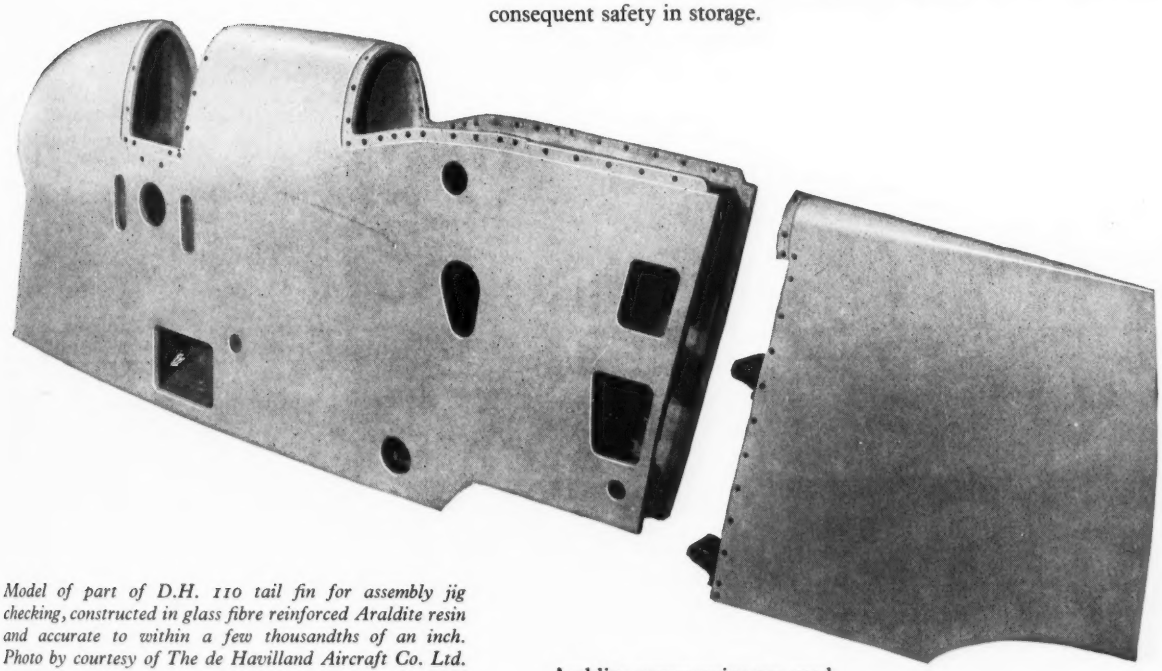

Model of part of D.H. 110 tail fin for assembly jig checking, constructed in glass fibre reinforced Araldite resin and accurate to within a few thousandths of an inch. Photo by courtesy of The de Havilland Aircraft Co. Ltd.

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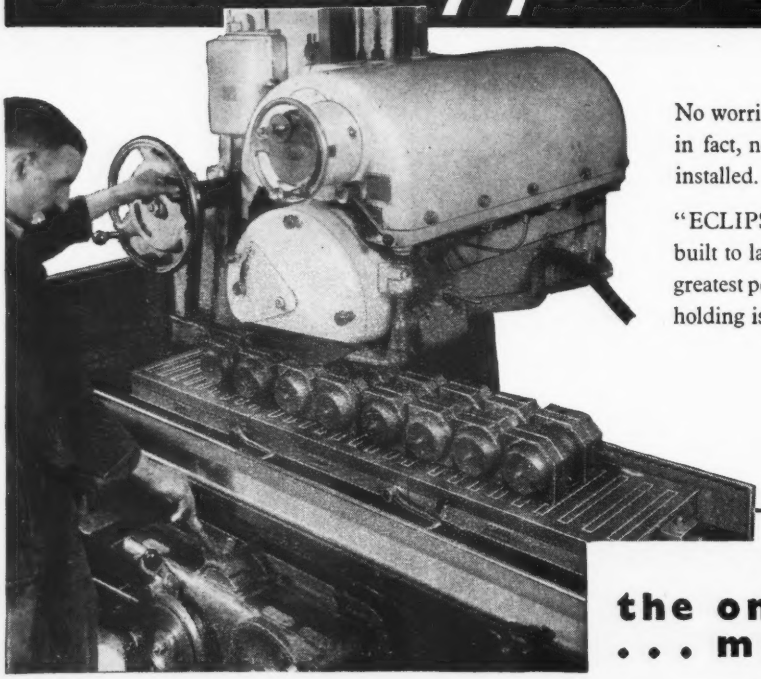

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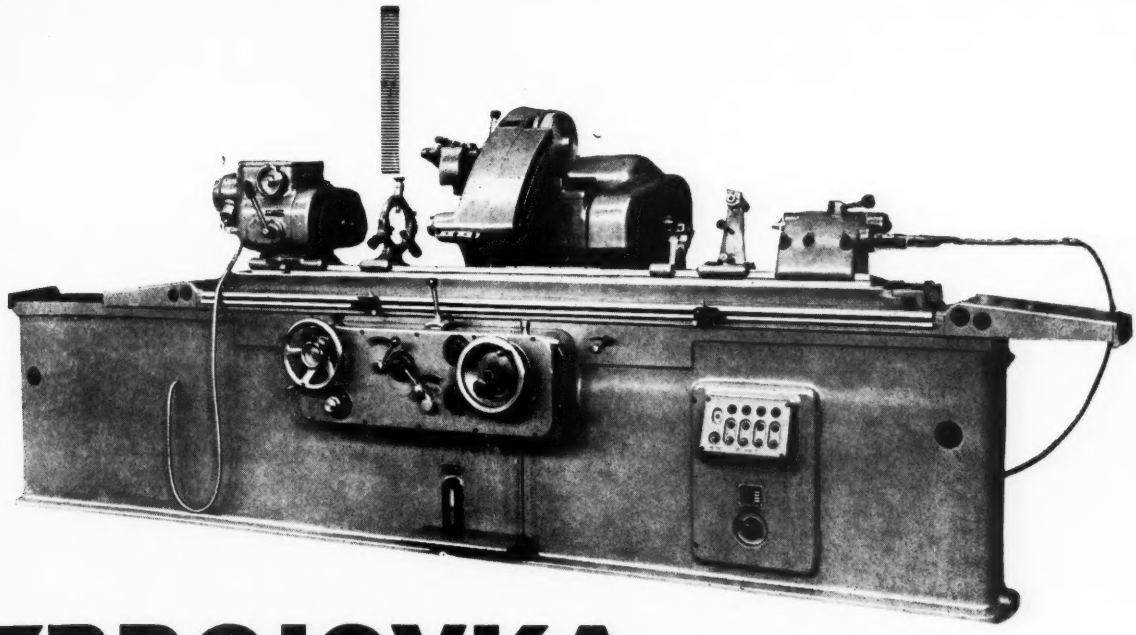

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Max. distance between centres	20"	30"	30"	40"	60"
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R.p.m. of work	50—750	50—750	25—750	25—750	25—750
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Table swivels by	6°	6°	6°	5°	5°
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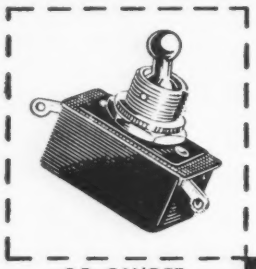

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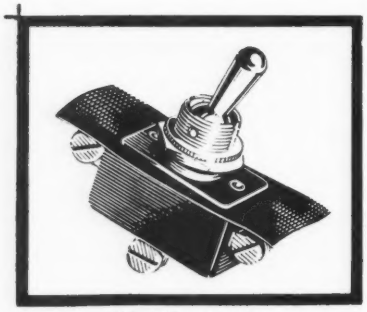

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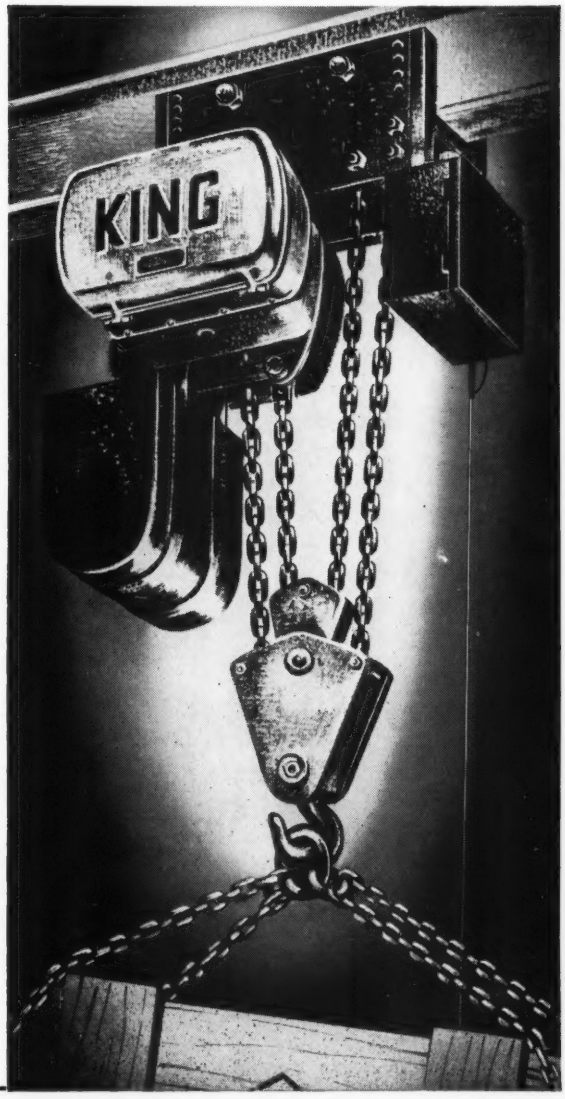

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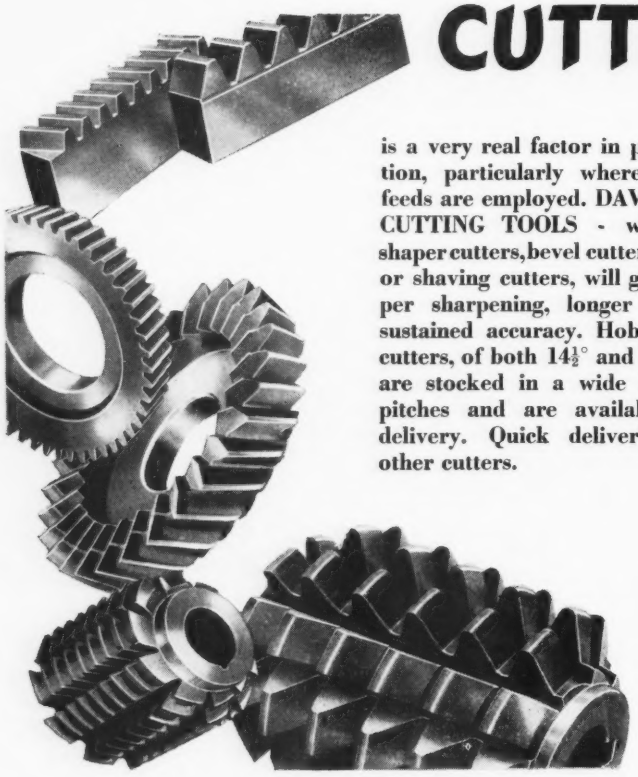

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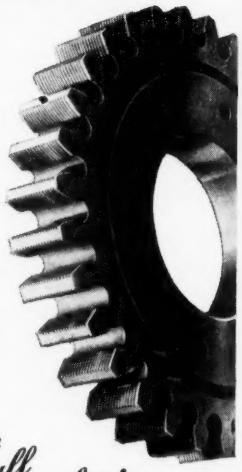

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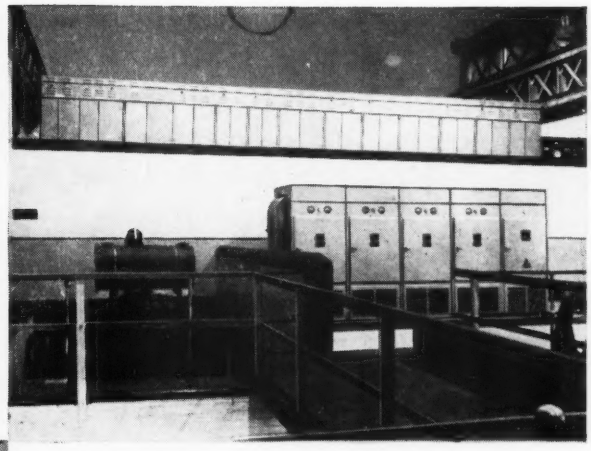

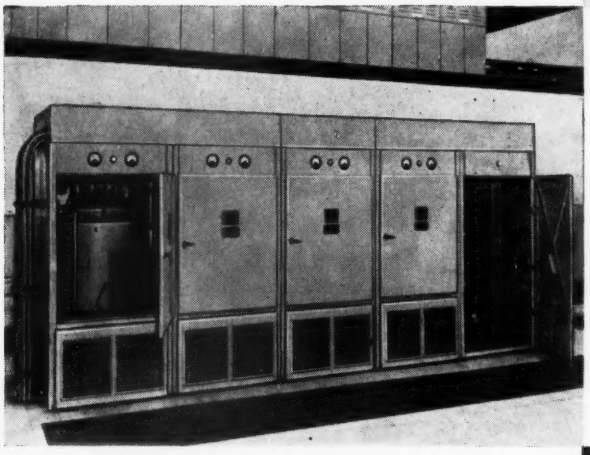

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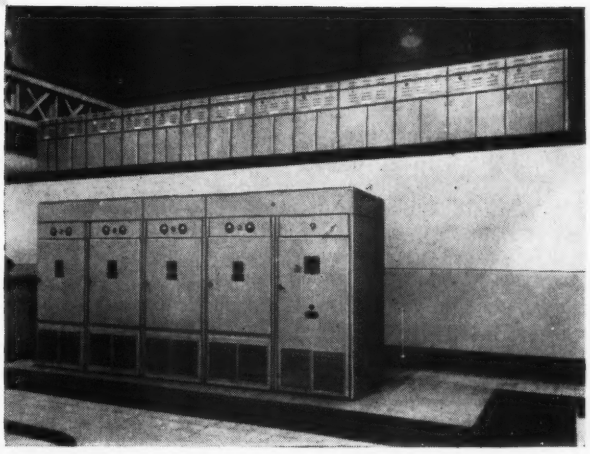

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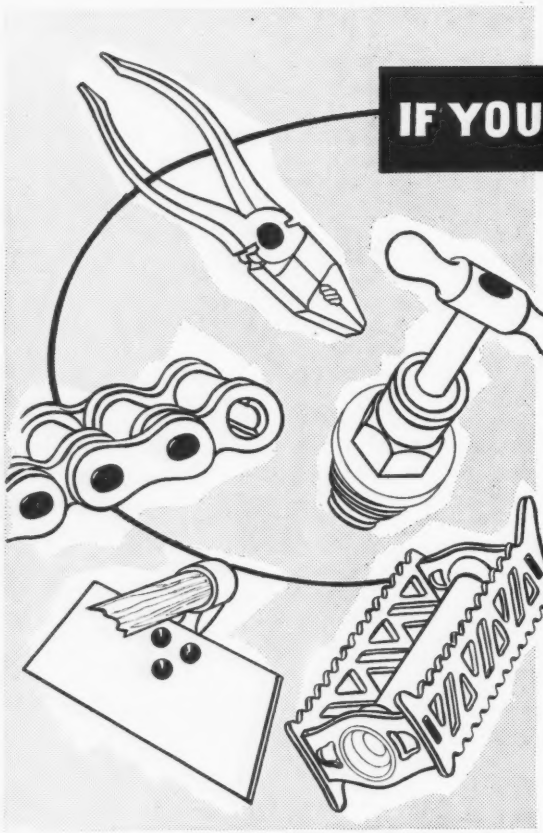

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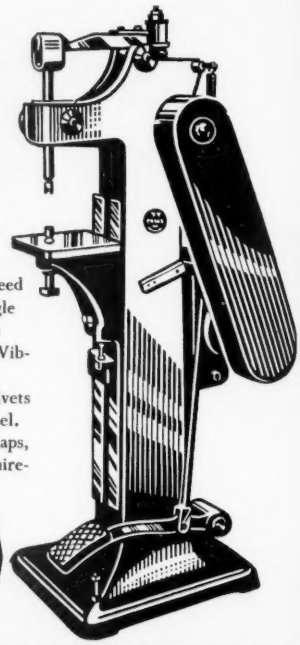

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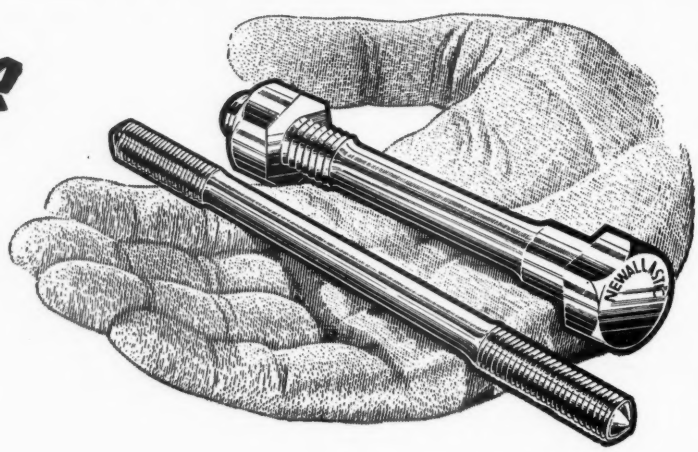

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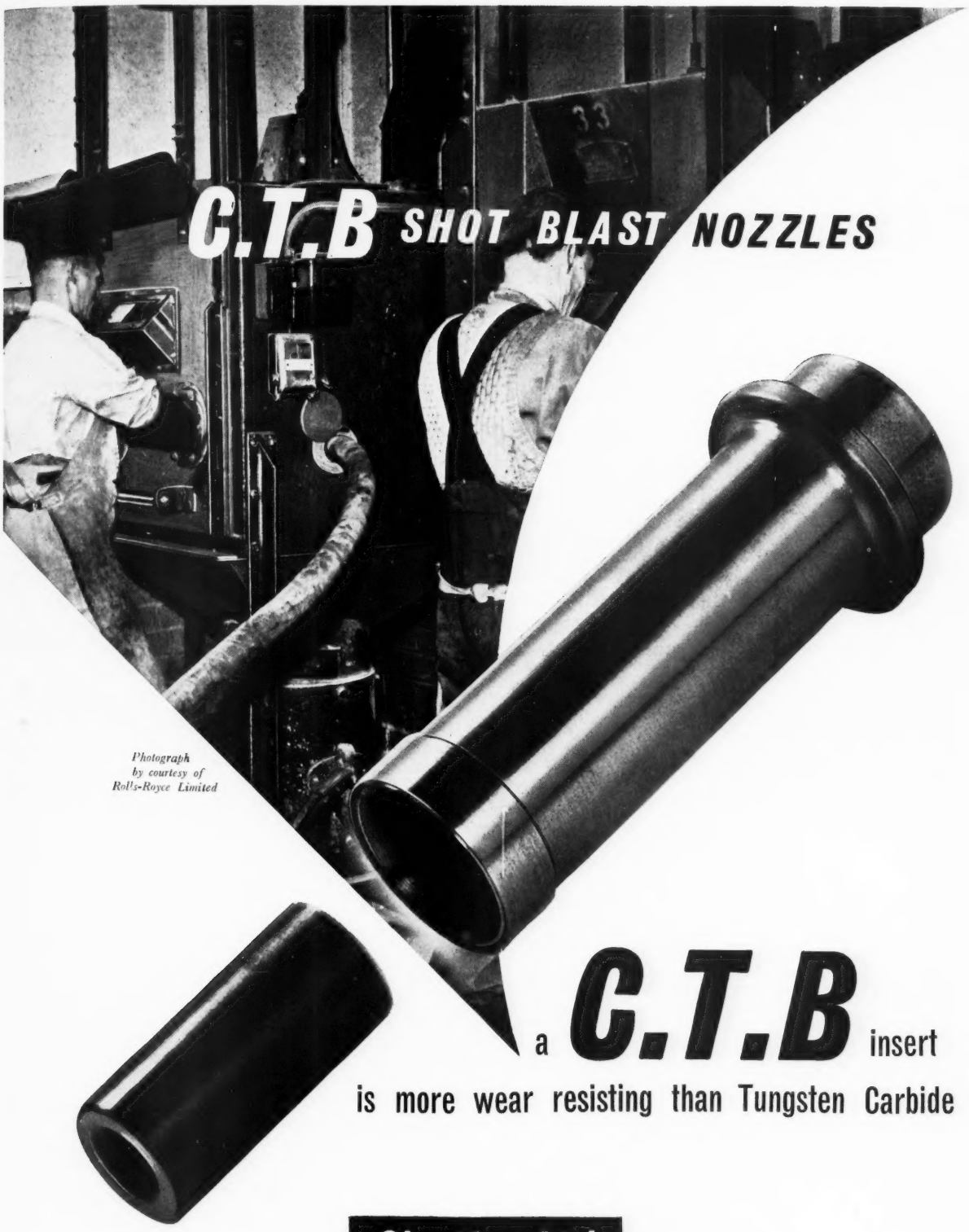

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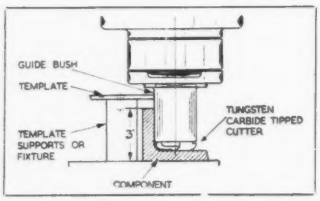

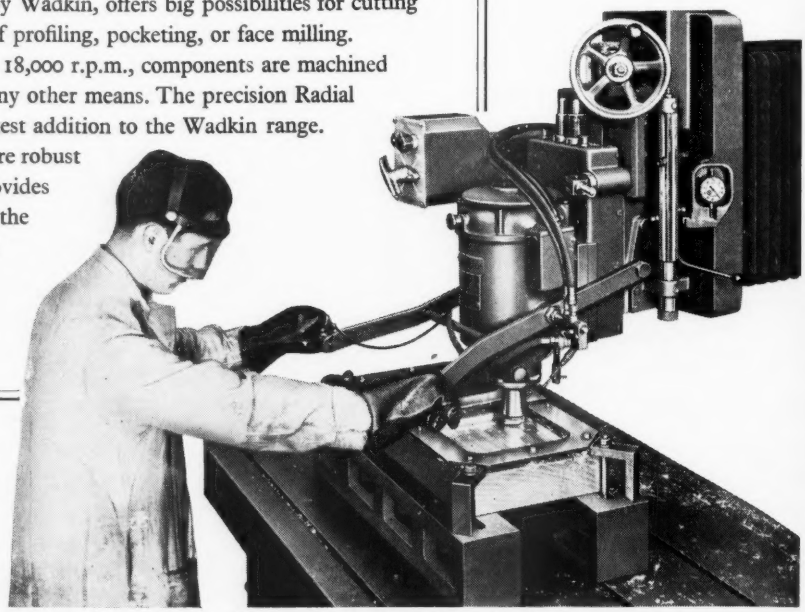

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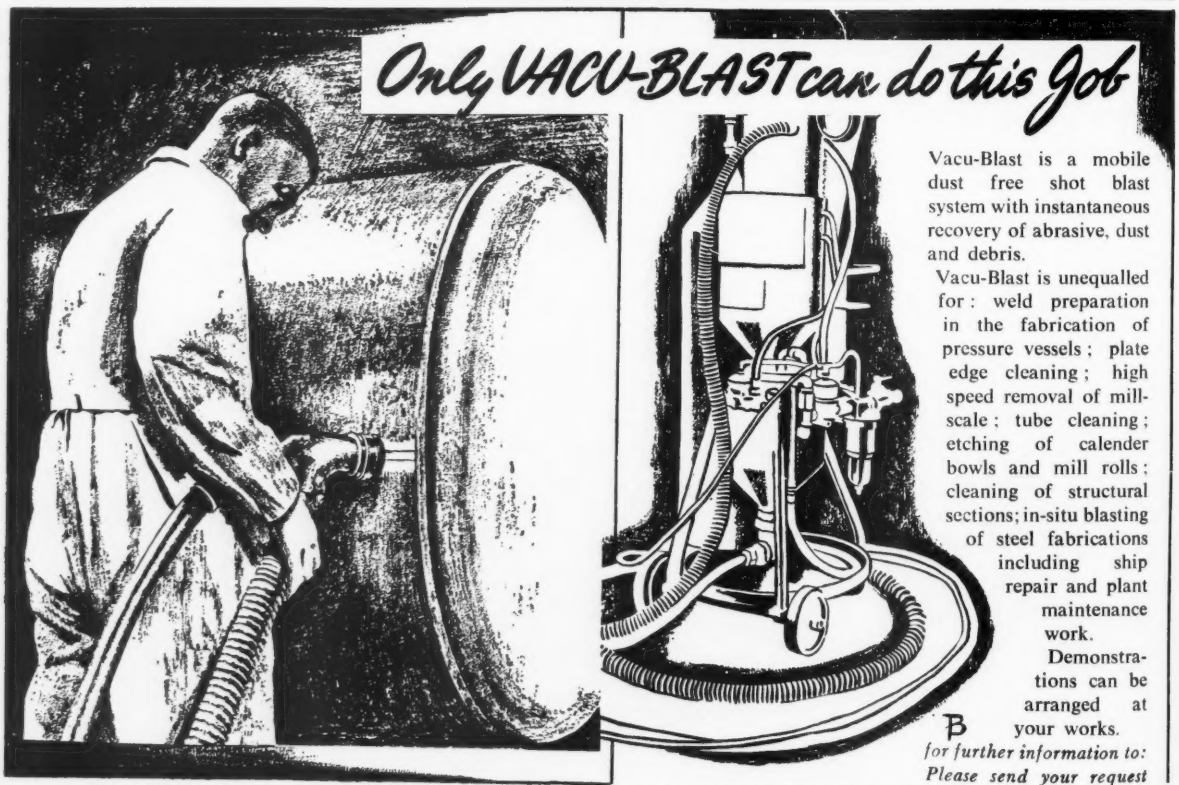

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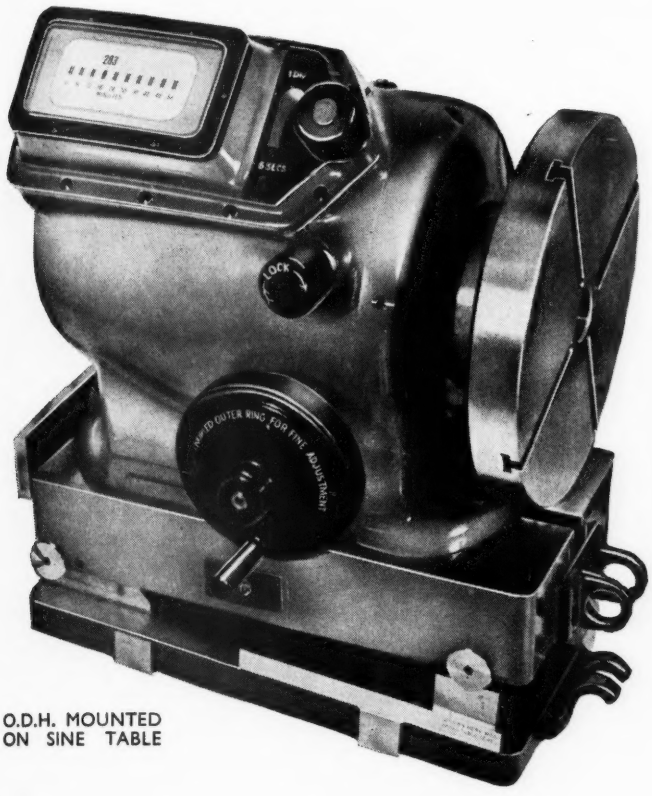

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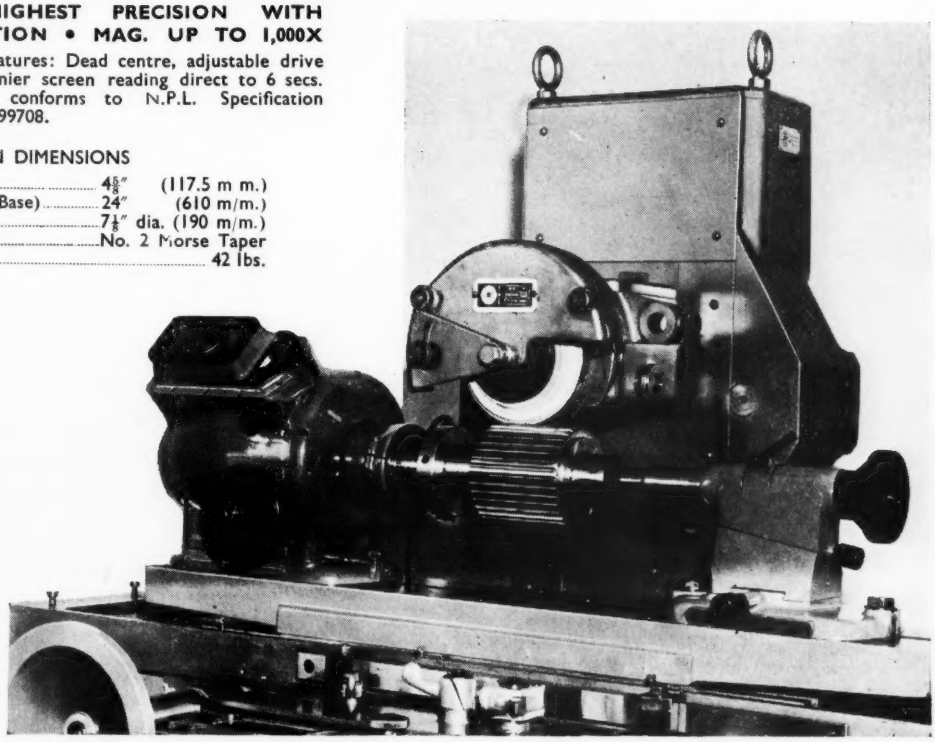

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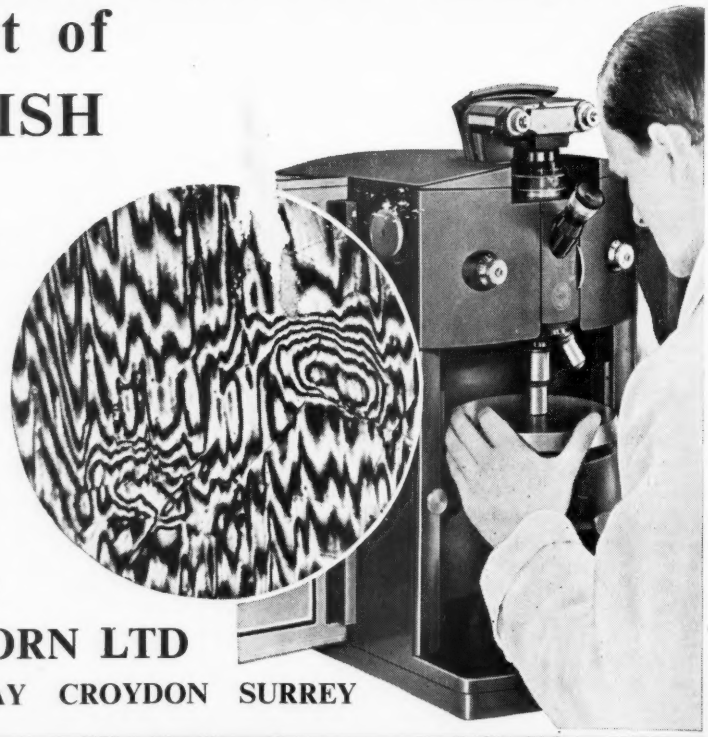
introducing an industrial microscope for the measurement of SURFACE FINISH



The Baker Surface Finish Microscope enables the research or production engineer to see the surface under examination magnified in *three* dimensions: the normal linear magnification of a microscope *plus* the heights and depths of surface contour mapped out by the interference fringes to an accuracy of one micro-inch. The inset shows turned aluminium alloy with grooves and areas where the metal has chipped out.

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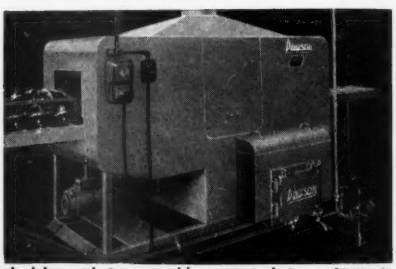
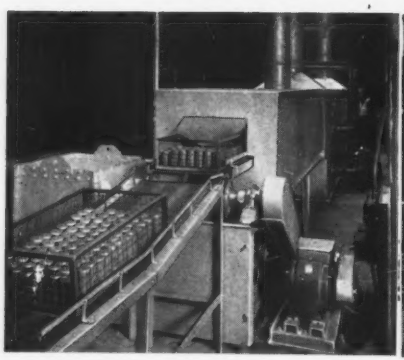


A 'Junior' type machine supplied to a Midlands Motor Car Works.



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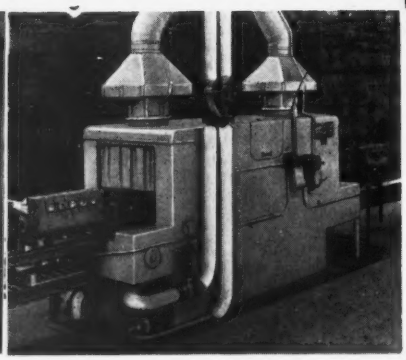
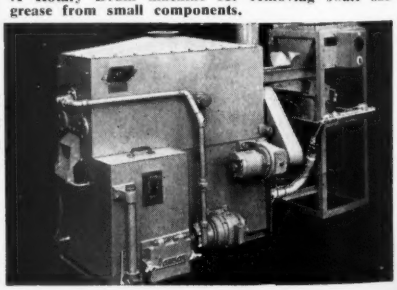


A model 'A' machine washing parts of motor car engines prior to assembly.

Dawson

DE-GREASING AND CLEANING MACHINES

A Rotary Drum machine for removing swarf and grease from small components.



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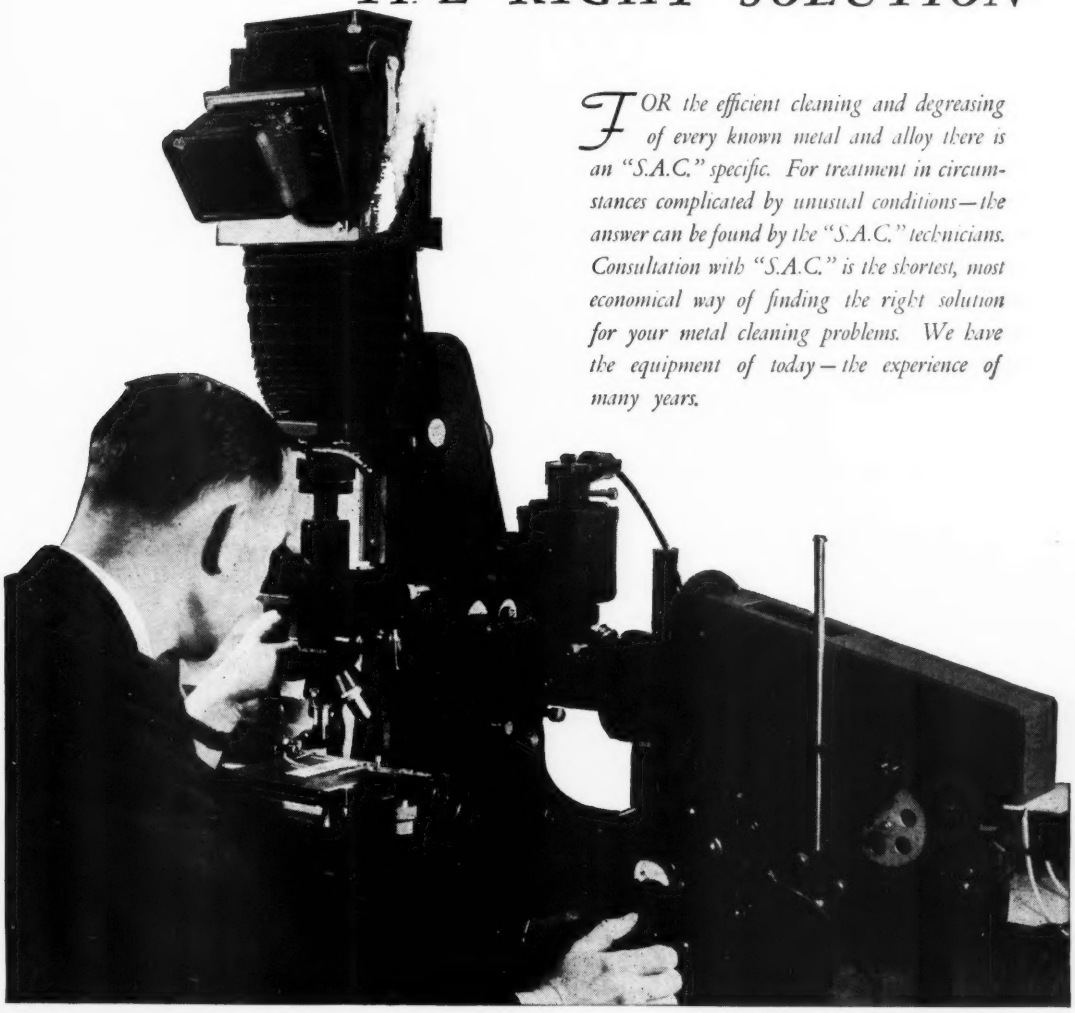

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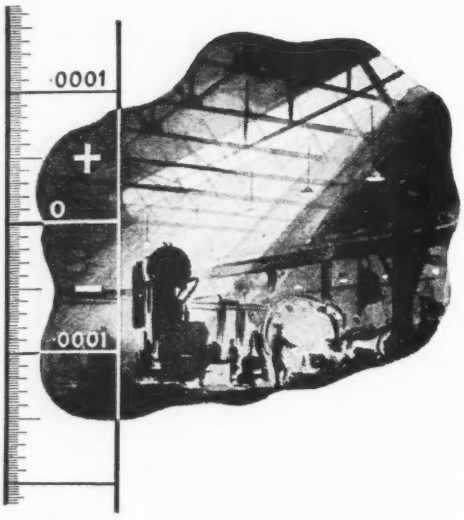

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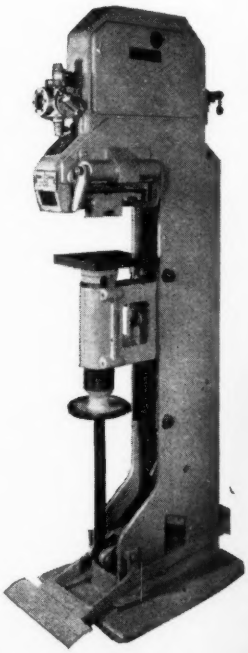

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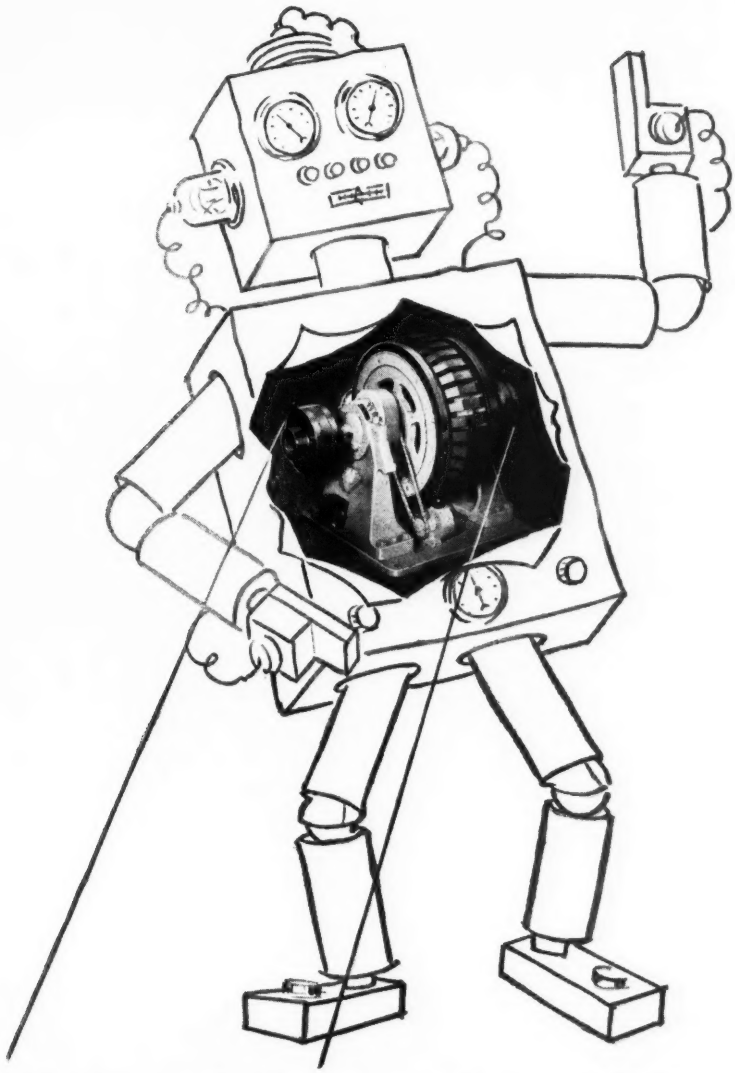

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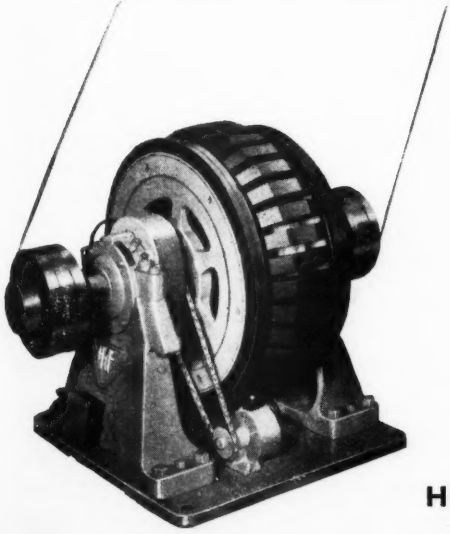

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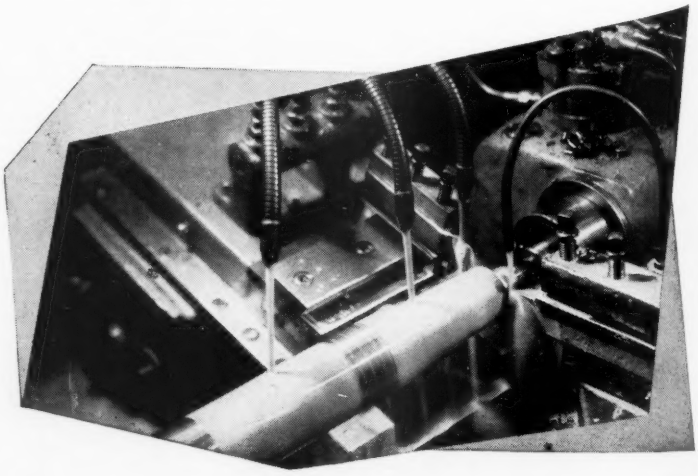

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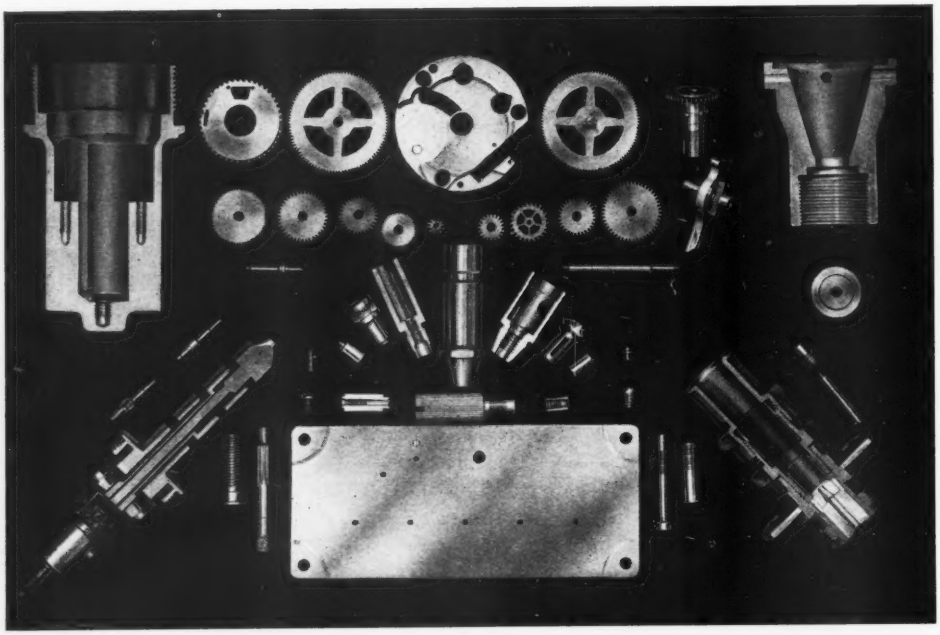

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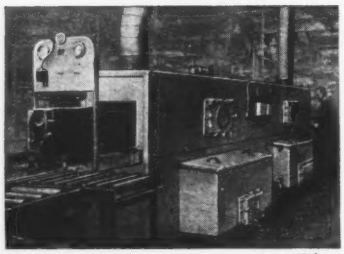
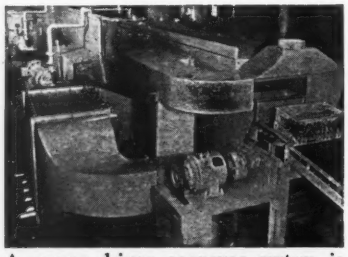
INDUSTRIAL CLEANING MACHINES

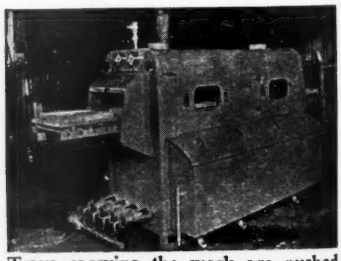
can be designed to meet your particular cleaning problems



This illustration shows a machine cleaning crank cases in the production line. It is equally capable of cleaning small parts in baskets.



A power driven conveyor system is employed with this cleaning machine for ball bearings.



Trays carrying the work are pushed through on a roller conveyor by hand in this cleaning installation.

Whilst offering a very wide variety of standard cleaning equipment, it is BRATBY policy, wherever possible to design the machine to meet the particular cleaning problem. Careful study of each individual problem ensures maximum efficiency and economy of the plant in operation. The illustrations show but a few of the specific types of Cleaning Machines designed by BRATBY for individual needs.

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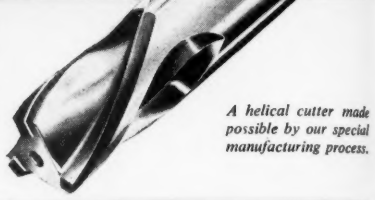

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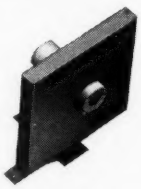

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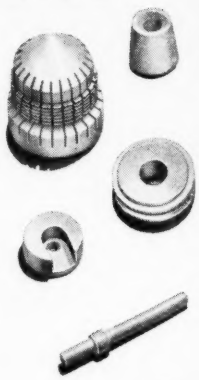

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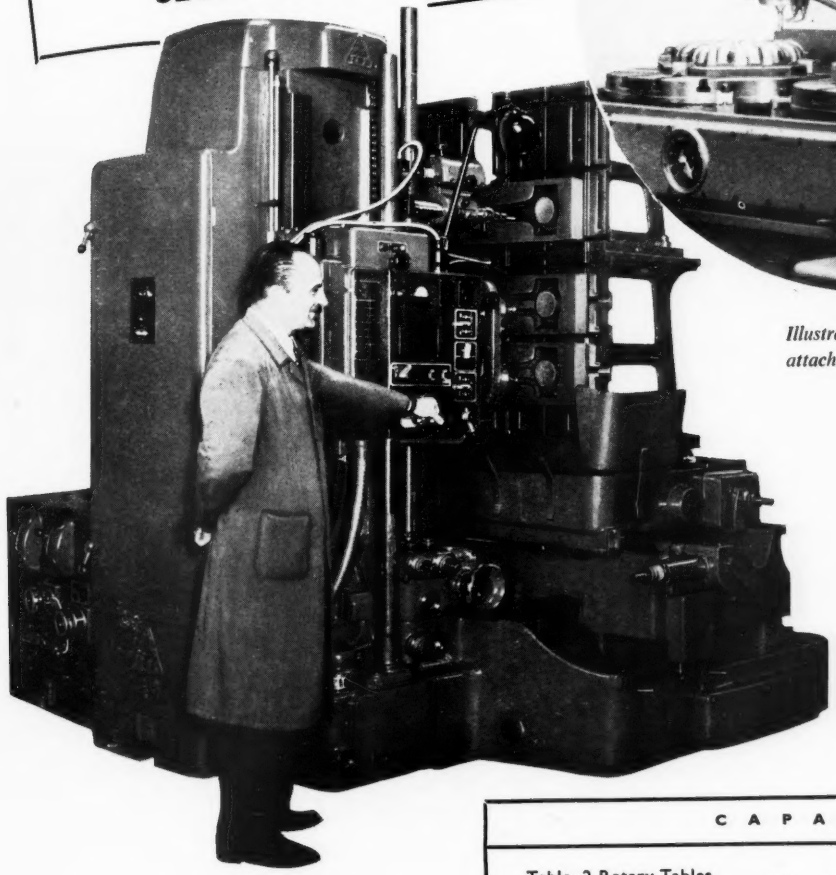

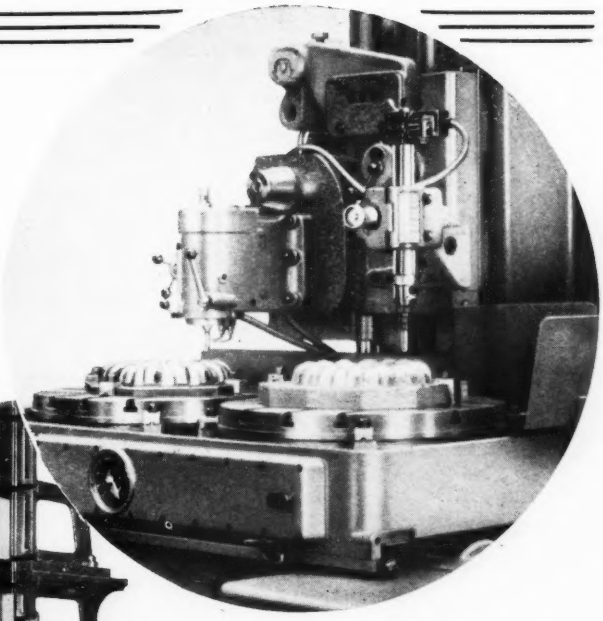

Illustration shows machine copying with vertical attachment fitted, and using the two rotary tables

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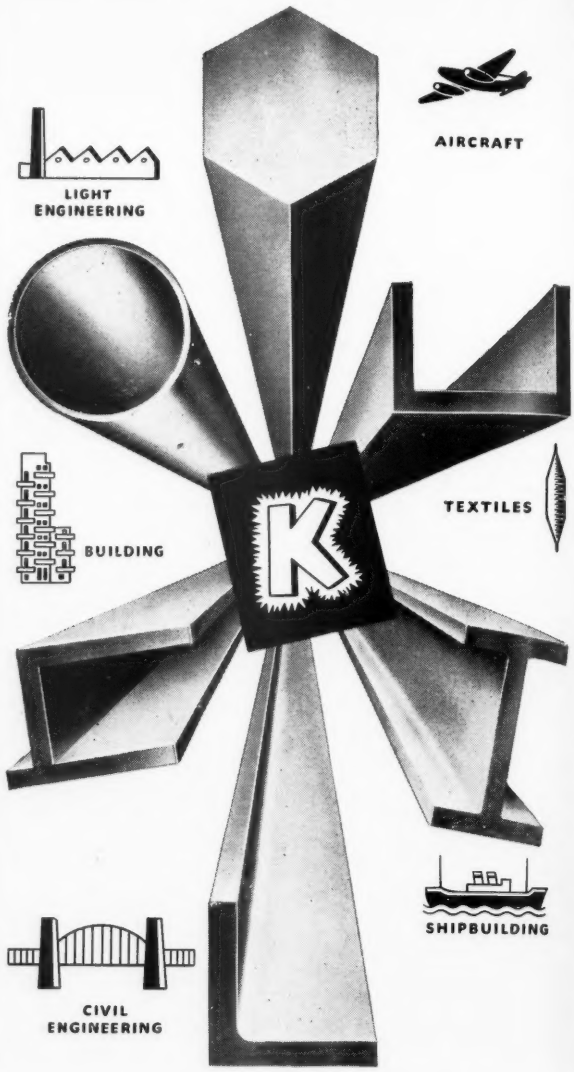

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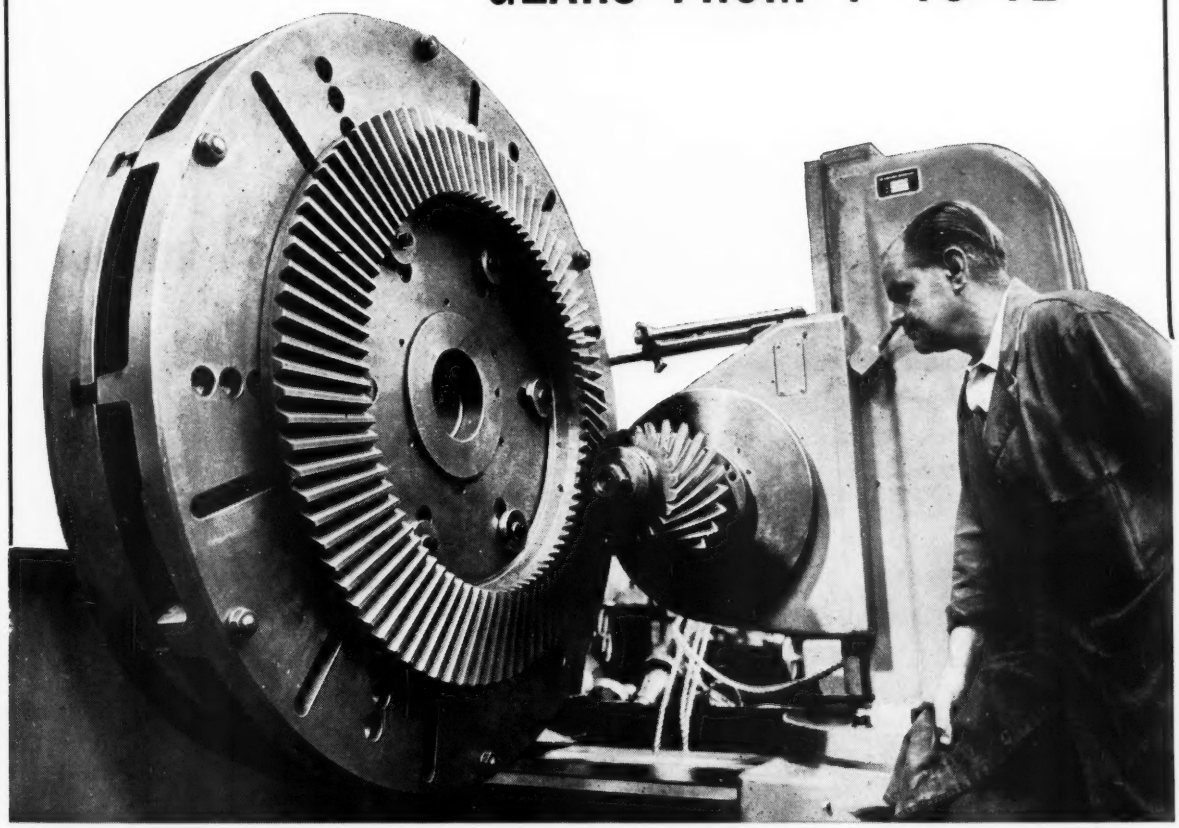

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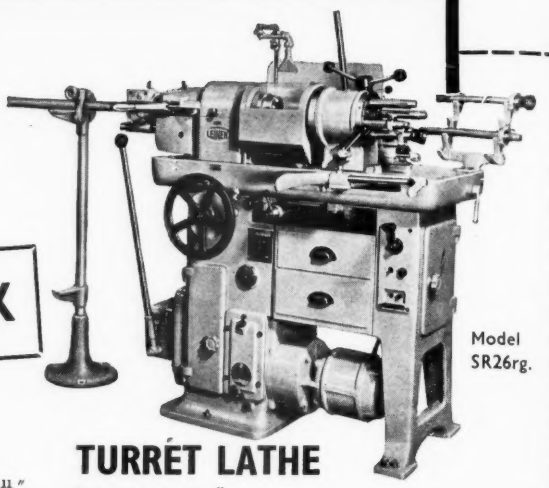

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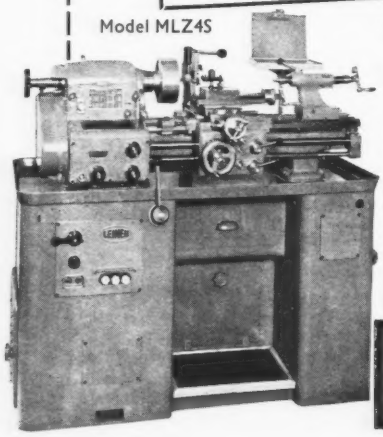

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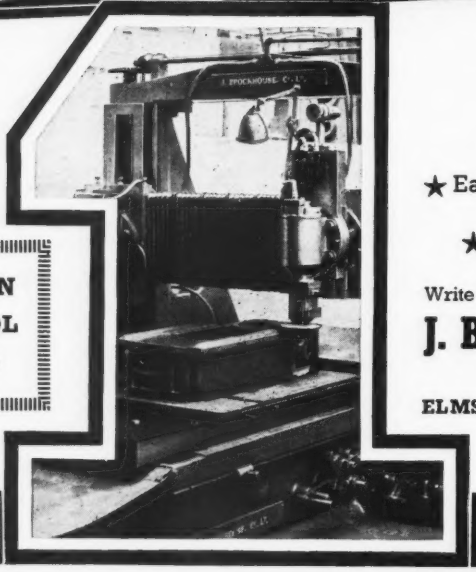

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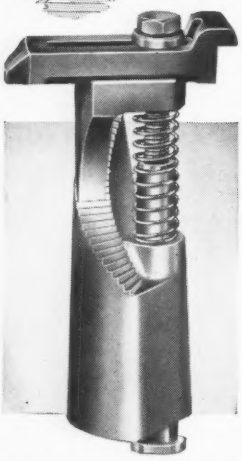

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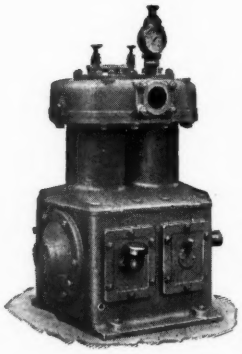

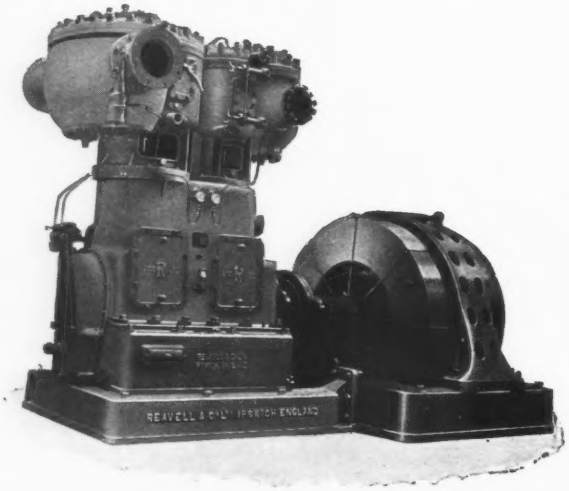

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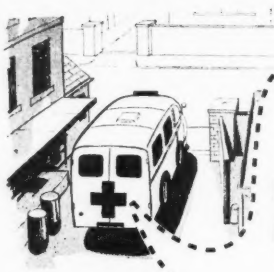

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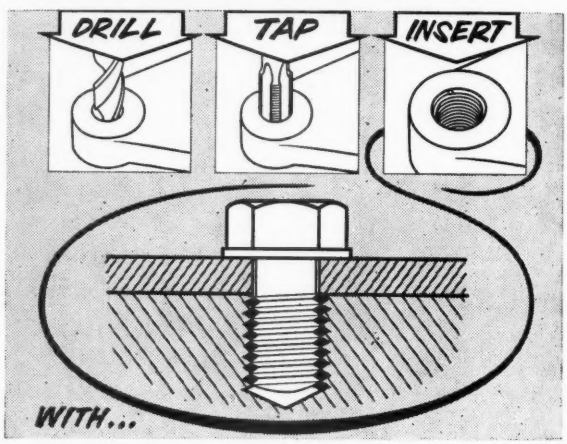

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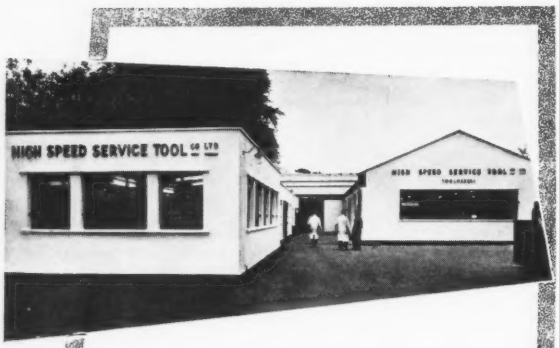

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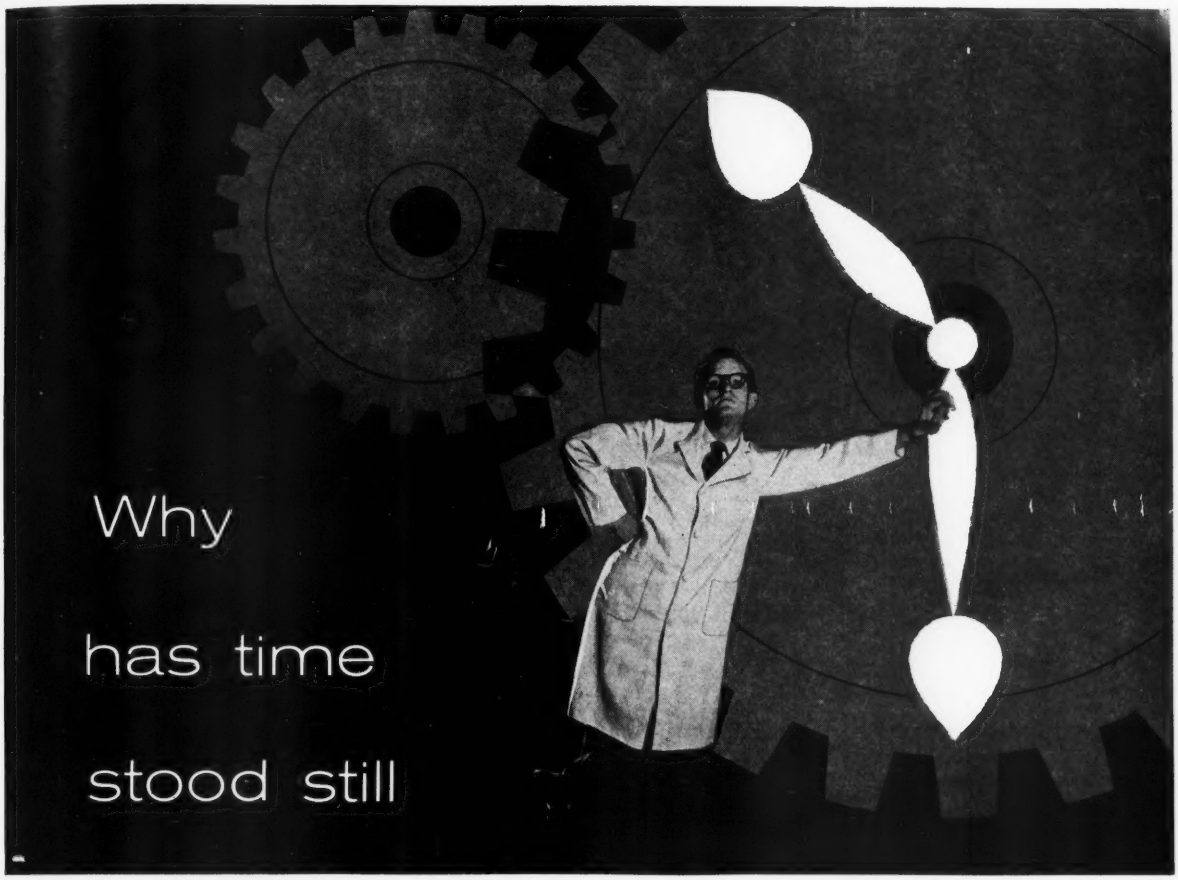

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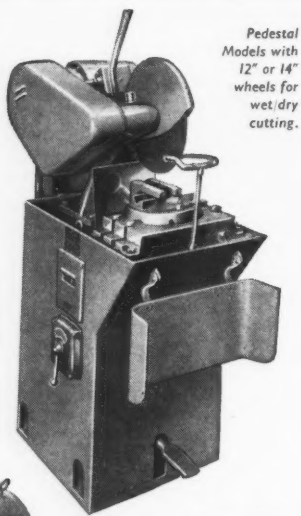

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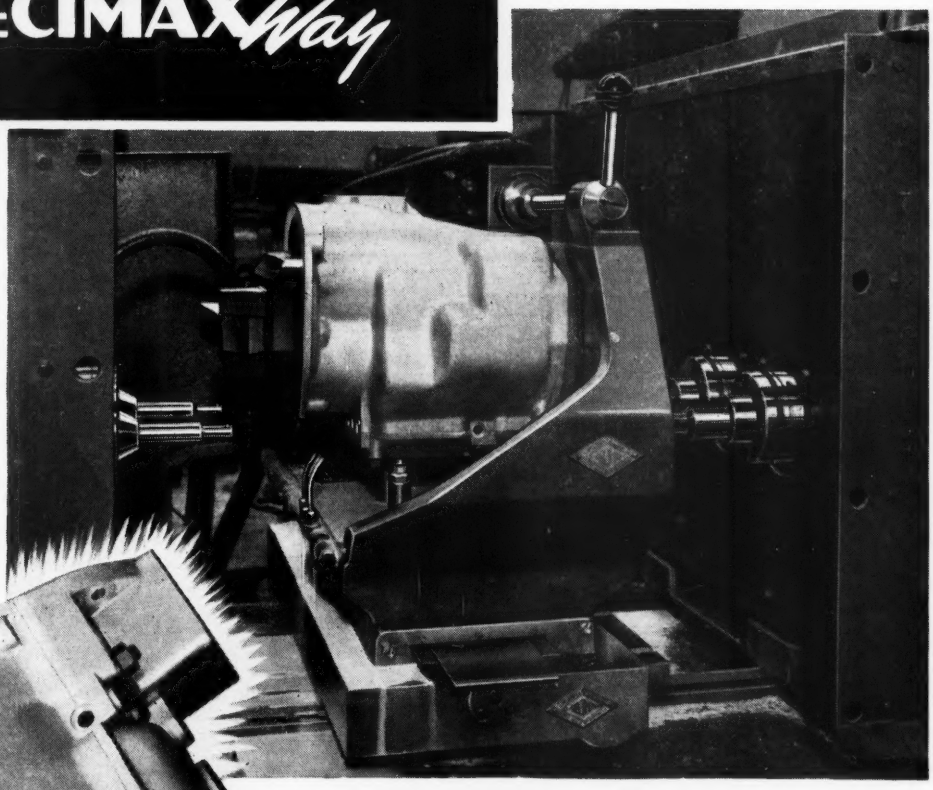

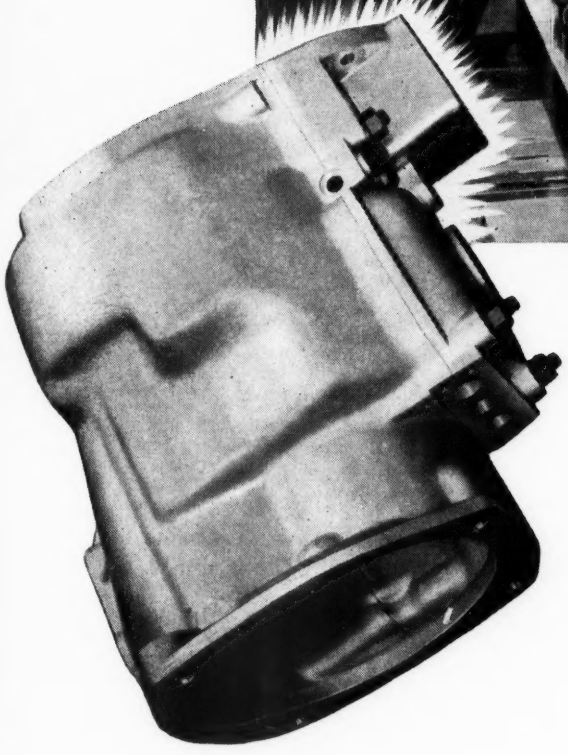

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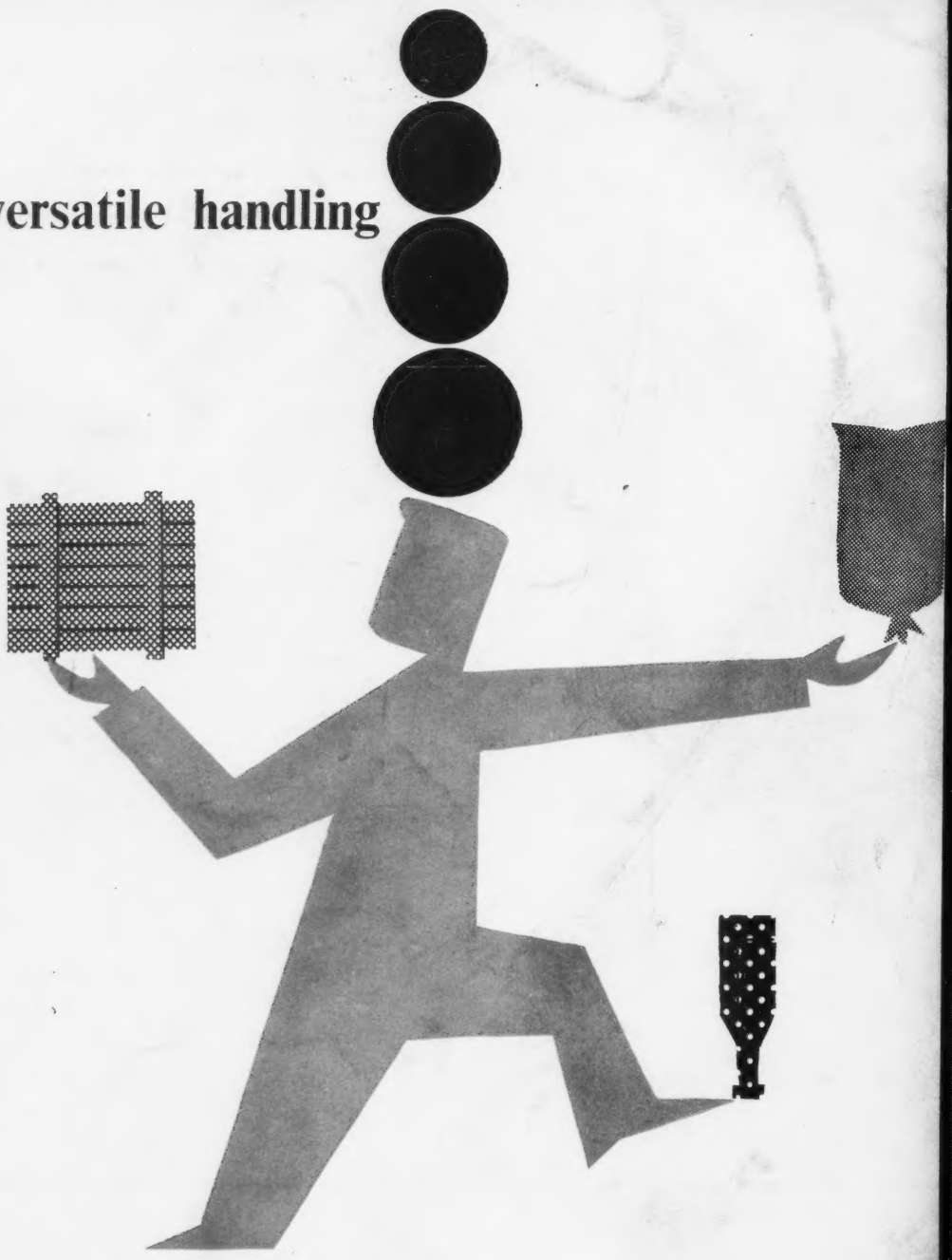

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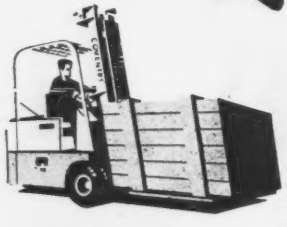

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